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STRATEGIES AND COGNITIVE PROCESSES IN CONCEPT LEARNING. FINAL REPORT.

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DESCRIPTORS- *CONCEPT FORMATION, *COGNITIVE ABILITY, ABILITY, *COGNITIVE PROCESSES, LEARNING PROCESSES, INFORMATION PROCESSING, THOUGHT PROCESSES, FACTOR ANALYSIS,

THE NATURE OF A CONCEPT WAS EXPLICATED IN TERMS OF FOUR CHARACTERISTICS--DEFINABILITY, STRUCTURE, PSYCHOLOGICAL MEANINGFULNESS AND UTILITY. A CONCEPT LEARNING STRATEGY WAS SEEN TO BE COMPRISED OF THREE SETS OF COGNITIVE PROCESSES--(1) ANALYZING SITUATION, (2) SECURING INFORMATION, AND (3) PROCESSING INFORMATION. A SERIES OF 19 CONTROLLED EXPERIMENTS AND FACTOR-ANALYTIC STUDIES WAS CARRIED OUT TO CLARIFY THE NATURE OF CONCEPT LEARNING STRATEGIES AND THEIR COMPONENT COGNITIVE PROCESSES. A TOTAL OF 2,062 ELEMENTARY, HIGH SCHOOL, AND UNIVERSITY STUDENTS SERVED AS SUBJECTS. INSTRUCTIONS FORMULATED TO ENABLE SUBJECTS TO COGNIZE THE ATTRIBUTES OF THE CONCEPT POPULATION AND THE RULE JOINING THE ATTRIBUTES, AND TO DRAW CORRECT INFERENCES FROM POSITIVE AND NEGATIVE CONCEPT INSTANCES FACILITATED CONCEPT LEARNING. SUBJECTS OFFERED HYPOTHESES IN A SYSTEMATIC PREDICTABLE PATTERN RELATED TO THE INFORMATION FEEDBACK WHICH THEY HAD RECEIVED. SUCCESSIVE PRESENTATION OF CONCEPT INSTANCES, RANDOM ORDER OF INSTANCE RECALL, AND SHORTER STIMULUS EXPOSURE TIME (VARIABLES ASSUMED TO INCREASE MEMORY LOAD) RESULTED IN POORER RETENTION SCORES. HIGH-ANALYTICAL SUBJECTS WERE SUPERIOR TO LOW-ANALYTICAL SUBJECTS IN ABILITY TO PROCESS INFORMATION AND ATTAIN CONCEPTS. FACTOR-ANALYTIC STUDIES RELATED AN INDUCTION FACTOR TO CONCEPT-ATTAINMENT TASKS, AND SUGGESTED THAT MORE COMPLEX CONCEPT LEARNING TASKS REQUIRE HIGHER-LEVEL ABILITIES THAN SIMPLER TASKS. (AUTHOR)

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Strategies and Cognitive Processes in Concept Learning

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Office of Education
Bureau of Research

PREFACE

Many individuals participated in this project and their contributions took many forms. Each of ten individuals who were employed on the project while graduate students at the University of Wisconsin wrote an M.S. thesis or a Ph.D. dissertation and thus simultaneously made an important contribution to the project. The student's name, present position, the title of the thesis or dissertation, and the major professor follow:

J. Kent Davis, Ph.D., Assistant Professor of Educational Psychology, University of Victoria; Concept Identification as a Function of Cognitive Style, Complexity, and Training Procedures; Herbert J. Klausmeier.

Wayne C. Fredrick, Ph.D., Research Associate, Wisconsin Research and Development Center for Cognitive Learning; Information Processing and Concept Learning at Grades Six, Eight, and Ten as a Function of Cognitive Style; Herbert J. Klausmeier.

Dorothy L. Jones, Ph.D., Assistant Professor of Education, University of Pennsylvania; Relationships Between Concept Learning and Selected Ability Test Variables for an Adult Population; Chester W. Harris.

Elmer A. Lemke, Ph.D., Associate Professor, Department of Education and Psychology, Illinois State University; The Relationship of Selected Abilities to Some Laboratory Concept Attainment and Information Processing Tasks; Chester W. Harris.

Gerald W. Miller, Ph.D., Assistant Professor of Educational Research and Testing, Florida State University; Retention and Concept Identification as Functions of Concept Complexity, Method of Presentation, Stimulus Exposure Time, and Conditions of Recall; Herbert J. Klausmeier.

James G. Ramsay, Ph.D., Assistant Professor of Educational Psychology, New York University; Concept Learning as a Function of Type of Material and Type of Classification; Herbert J. Klausmeier.

Marcus, C.S. Fang, M.S., graduate student, University of Wisconsin; Effect of Incentive and Complexity on Performance of Students from Two Social Class Backgrounds in a Concept Identification Task; Herbert J. Klausmeier.

Patricia W. Kalish, M.S., homemaker; Concept Attainment as a Function of Monetary Incentives, Competition, and Instructions; Herbert J. Klausmeier.

Daniel O. Lynch, M.S., Assistant Professor of Educational Psychology, University of Wisconsin-Oshkosh; Concept Identification as a Function of Instructions, Labels, Sequence, Concept Type, and Test Item Type; Herbert J. Klausmeier.

Nancy S. Smuckler, M.S., homemaker; Concept Formation as a Function of Presentation and Ratio of Positive to Negative Instances; Herbert J. Klausmeier.

The preceding students also participated in other data gathering and project activities. In particular, J. Kent Davis served as project coordinator for three years, carrying out policies established by the principal investigators and assisting in planning and executing most of the 19 experiments reported. Wayne Fredrick, Daniel Lynch, and Gerald Miller also participated in gathering data for experiments not reported in theses and dissertations.

Much useful detailed information is presented in the theses and dissertations, each of which is bound and on file at the Memorial Library, University of Wisconsin. Each reflects the style of the writer and to a lesser extent the major professor. The great amount of detail could not be incorporated in this final report. Elizabeth Schwenn and Dorothy Frayer, also graduate students at the University of Wisconsin, assumed primary responsibility, with Herbert J. Klausmeier, for reviewing the theses, dissertations, and other experimental data and for preparing the 19 reports of experiments contained in the final report. The roles of these three are summarized at the beginning of each section of experiments and credit is given to relevant thesis and dissertation writers.

Chester W. Harris contributed to the conceptualization of the problem area, and of specific problems, the design of the experiments, and the statistical analyses throughout the project. Besides serving as major professor to the two students who did the factor analytic studies, he was on the thesis committee of most of the other students. Throughout the project, he offered constructive critical review and editorial advice to individuals preparing the original reports and the final report.

Herbert J. Klausmeier assumed administrative responsibility for the project, including the preparation of reports to U.S.O.E. Most of the data were gathered by students under his supervision and he led the weekly planning and discussion meetings. The accuracy of the information presented herein and the interpretations regarding strategies, cognitive processes, and nonprocess variables were his concerns. The summary and introduction were written by

him with many helpful suggestions from Wayne C. Fredrick, Dorothy Frayer, and Elizabeth Schwenn. Mrs. Dorothy Cullen and Mrs. Arlene Knudsen typed the final report and prepared it for reproduction.

Herbert J. Klausmeier, Professor
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SUMMARY

This project is summarized in terms of conclusions that were drawn regarding (a) the nature of concepts, (b) strategies and cognitive processes in concept learning, and (c) the relationship of various stimulus and instructions variables to concept learning. Conclusions based on statistically significant treatment effects and in line with conclusions of other researchers are given primary attention. Implications are outlined for each set of conclusions.

Nature of Concepts

Until 1965, an operational definition of Concept (a concept of concept) was used by the present investigators, who are psychologists. In October, 1965, a conference was held at the Wisconsin Research and Development Center for Cognitive Learning involving scholars in education, philosophy, psychology, and various subject fields. At this conference, reported in *Analyses of Concept Learning*, Academic Press, 1966, it became apparent that any particular operational definition of Concept was acceptable to only a minority of the participants, mainly psychologists, and not to experts in various subject matter fields. The further conclusion was that the bases for defining concepts vary markedly across disciplines and to a lesser extent within disciplines. In turn, the varying bases reflect real differences in the nature of concepts and also the diverse frames of reference of scholars.

During the three years of this project, populations of concepts were devised as prototypes of "real-life" concepts and were used as stimulus material. Also, the concepts in various disciplines were studied. From these activities a definition of Concept was formulated that clarifies the types of concepts to which the conclusions of this project may apply.

An analogy between Concept and the concept of a dog may be helpful. A dog is a domesticated, carnivorous mammal of the family, Canidae; in other words the concept, dog, is comprised of the defining properties by which all instances of dogs are put into the same category and also by which dogs are discriminated from other animals. Similarly, Concept is defined as a product of learning, or, more broadly, of mankind's experience, having four characteristics--definability, structure, psychological meaningfulness, and utility. Treating Concept, the superordinate category of which all concepts are instances, in terms of defining characteristics should assist scholars in various disciplines, and also curriculum developers, to identify concepts and to differentiate concepts from other products of learning in the cognitive domain such as facts, principles, and problem-solving skills. The term, characteristic, is used when referring

to Concept. The terms, property and attribute, are used interchangeably when referring to concepts. The different terms are used to facilitate reading and understanding.

One characteristic of Concept is definability. This characteristic was inferred from definitions given by experts to concepts in their respective disciplines and from definitions given in dictionaries. The latter are definitions that are widely shared by individuals who speak the same language. Four bases of defining concepts were identified as follows: (a) in terms of perceptible or readily measurable properties, (b) semantically, in terms of synonyms, antonyms, and other semantic meanings, (c) operationally, and (d) in terms of axioms, or logical or numerical relationships. The four definitional bases, examples of concepts corresponding to each basis, and one denotative meaning--equivalent to the concept when only this one characteristic of Concept is considered--will clarify the definability characteristic of Concept.

Basis of definition	Examples of concepts	Denotative meaning
Perceptible defining properties	Dog, tree, yellow, sentence, Congress, running, inanimate	Dog--a domesticated, carnivorous mammal of the family Canidae
Semantically	Polite, pretty, praise, liberal	Polite--marked by an appearance of consideration, tact, or deference; by a lack of roughness or crudity.
Operationally	Hunger drive, intelligence, learning, social class	Hunger drive--an internal condition expressed as a linear function of the amount of elapsed time since food intake
Logical or numerical relationships, or axioms	Mass, ratio, rate, parallel lines	Mass = $\frac{\text{force}}{\text{acceleration}}$ Parallel lines--lines extending in the same direction and everywhere equidistant

The preceding definitional bases are not mutually exclusive. Whether an expert judges that a concept, for example, liberal, is best treated in terms of perceptible defining properties or in terms of semantic meanings is dependent upon his criteria of perceptible properties and semantic meanings. Similarly, operational definitions merge with logical relations when the psychologist or other scholar defines a concept operationally and in terms of quantitative relations. Also, a concept, such as of learning, might be verbalized by a psychologist in a precise operational definition and the concept of parallel line

might be defined axiomatically by the mathematician; however, the large proportion of Americans may be satisfied with synonyms, antonyms, and examples when defining the same concepts.

The second characteristic of Concept is structure. This characteristic was also inferred from studying concepts in various disciplines and developing populations of concepts for experimental study that would serve as models of large numbers of concepts in various disciplines. The structure of concepts is determined by the form in which the concepts are experienced; the defining properties including semantic meanings, and quantitative or other relations; the rules by which the properties are joined; and the instances of the concept. The four structural components and the dimensions of each follow:

Structural Element	Principal Dimensions
Form in which the concept, instances and properties are experienced.	Figural--open to sensory modalities, including touch and kinesthetic. Symbolic--words and other symbols. Behavioral--feelings of an affective type.
Properties that define the concept.	Number--one to many. Relevance--relevant or irrelevant. Discriminability--easy to difficult. Molecular-molar--single unit to complex grouping.
Rules that join the properties.	Simple affirmation--red. Conjunctive--red, domesticated, and carnivorous. Disjunctive--red, domesticated and/or carnivorous. Relational--all the red, domesticated and one of the carnivorous.
Instances of the concept.	Number Discriminability Member-Nonmember

The third characteristic of Concept is psychological meaningfulness, referring to the phenomenological or idiosyncratic nature of concepts. Some experts define concepts only in terms of this idiosyncratic characteristic. The internal representations that comprise the concepts held by the individual are referred to by psychologists as "network of inferences," "implicit mediating responses," or more broadly, as hypothetical constructs. The psychological meanings of any concept vary widely among individuals of the same age. Also, the concepts an

individual possesses change from infancy through adolescence into adulthood with increasing experience with the properties, rules, and instances of the concept and also with developmental changes in cognitive processes.

The fourth characteristic of Concept, utility, is directly related to the characteristic of psychological meaningfulness in that the utilization of a concept by an individual is dependent upon how well he has formed the concept. Concepts are used by the individual (a) to reduce environmental complexity as instances are categorized and as concepts themselves are related to superordinate categories, (b) to identify objects, events, and states when encountered for the first time, (c) to reduce the necessity for relearning how to classify instances and label them, (d) to direct instrumental activities, and (e) to order and relate classes, not only instances, of objects, events, and states.

Consideration of two concepts, represented by the words dog and mass, will serve to summarize the defining characteristics of Concept and assist with their application.

Dog

Basis of definition:	Perceptible properties--those associated with domesticated, carnivorous, mammal, and Canidae.
Structure	
Instances:	There are many instances that may be experienced through various sensory modalities and readily discriminated from other animals except non-dog members of the family, Canidae. All animals that are not dogs may be treated as negative instances and all other nonanimal objects may be treated as noninstances.
Properties:	There are many values associated with carnivorous, mammal, and Canidae that are, in turn, clearly defined in a taxonomic system. The properties and values are perceptible and readily discriminated, except the properties and values to differentiate between dogs and other non-dog members of the Canidae family; e.g., foxes and wolves. The properties are relatively molar since flesh-eating, hairy, and mammary glands each include many other subattributes or subconcepts.
Rules for joining properties:	Conjunctive.

Psychological meaningfulness:	Many children early in life properly categorize positive instances and negative instances of dog; subsequently they acquire the correct label for the concept. Somewhat later they discriminate the various properties and acquire the correct labels for the properties. Few adults fail to categorize dogs; however, the majority probably cannot give all the relevant defining properties and values for discriminating among wolves, dogs, and bears.

<u>Mass</u>

Basis of definition:	Logical relationship--"A resistance to change in motion" which implies a mathematical relationship between mass, force, and acceleration. The definition rests on an operation rather than visual cues.
Structure	
Instances:	There are countless objects, large and small, that manifest mass that may be experienced through the kinesthetic senses. Negative instances of mass exist in the sense that the set of all characteristics of an object such as weight, volume, number, color, etc., may be considered negative instances, while space and time are of a different order and may be considered noninstances of mass.
Properties:	Mass may be viewed as having only one property that can be precisely measured by an operation. The property is molecular since it is basic to other concepts.
Rule for joining properties:	Affirmation
Psychological meaningfulness:	Persons probably possess the concept at an operational level, but since it rests on a logical relationship, the verbal statement of it will often not be available. People who have studied physics possess the concept at higher levels of meaningfulness.

A search for documents that outline the "structure" of various disciplines failed to identify any reasonably concise listing of concepts at any school level, much less a hierarchically organized set of concepts. More important, the search for definitions by scholars that might be useful in identifying and classifying concepts showed wide variations.

Therefore, an analysis of concepts such as summarized in the previous pages shows that a precise definition of Concept in terms of characteristics may be useful in research on concept learning and also in curriculum development.

Strategies and Cognitive Processes

In Project 1442, a strategy was defined as a cognitive control, or plan, for executing three configurations of processes to be described later. Variants of two strategies were identified by analyzing the consecutive responses of subjects in a series of concept attainment experiments. One main strategy was a conservative focusing strategy characterized by the subject's successively selecting instances that varied in one attribute from the focus card to ascertain which attributes comprised the concept. Had the stimulus material been less complex or had the subject been given more complete instructions, he might have tested and eliminated successive hypotheses rather than attributes. The second main strategy was a gambling strategy characterized by the subject's selecting instances, the attributes of which varied more than one from the focus card. Subjects tended not to persist in this strategy but to adopt and persist in a conservative focusing strategy.

On the basis of the objective criteria for identifying strategies, three sets of process configurations involved in concept learning were identified--cognizing the definitional basis and structure of the concept population, selecting or responding to the instances to identify the properties and rules comprising the concept to be attained, and processing the obtained information. In turn, the component processes, or operations, related to each process configuration required identification and clarification. This analysis permits a more precise definition of global strategies that control the more specific cognitive processes.

The purposes of this project then were to identify and clarify the component processes related to three process configurations, and also to clarify the global strategy, or cognitive control of these processes.

In Figure S.1 is presented a tri-level hierarchical arrangement of the processes in concept learning, which processes are guided by an overall strategy, or plan. The numbers refer to experiments in the present project, designed to clarify processes. The experiments are reported later. The experimental results in terms of conclusions regarding the component processes are now summarized as a clarification of Figure S.1. Later in this section relations among the process configurations and strategies are discussed.

Beneath the broken line of Figure S.1 are noted the elementary processes

Global Strategies for Attaining Concepts

Analyzing the situation--the whole and its components	Securing information--searching for the attributes and rules that define the concept to be attained	Processing information--discriminating —> cognizing —> hypothesizing —> remembering —> evaluating —> inducing and/or deducing attributes, rules, and eventually the concept
Cognizing the definitional basis of the concept population in terms of perceptible defining attributes, semantic meanings, operations, relations, or use (1), (2), (3) Cognizing the structure of the concept population--instances, attributes, rules for joining attributes, and their relations (1), (2), (3), (11), (12), (13) Cognizing the task requirements (1), (2), (3)	Selecting instances from a total array to identify the defining attributes and rules Responding to instances presented simultaneously or consecutively to identify the defining attributes and rules Responding to propositions presented simultaneously or consecutively to identify the defining attributes, rules, or concepts	Inferring the concept by inductively arriving at the common defining properties and rules (14), (15); by cognizing logical relations among properties and rules (14) Evaluating relations among attributes or values and rules in terms of an hypothesis (15) Remembering attributes, rules, and hypotheses (7), (8), (9), (10) Hypothesizing relevant attributes (4), (5), (6) Cognizing a relevant attribute or rule by comparing the information presented in positive and negative instances (1), (2), (3), (13), (14) Cognizing that two or three instances do or do not belong to the same set (13), (14) Discriminating the relevant from the irrelevant characteristics of the stimulus situation (13) - - - - - - - - - - Cognizing common properties of at least two instances and responding with the appropriate single label Discriminating among many stimuli and responding appropriately Acquiring labels and associating proper labels with each stimulus situation Associating sequential S-R associations Associating responses with stimuli along physical dimensions Acquiring or manifesting non-labeling responses Sensing external and internal stimulus situations

Figure S.1. Hierarchical Arrangement of Cognitive Processes in Concept Learning

involved in initially learning a concept. The processes are outlined beginning with sensory experiences at birth and extending through the child's properly giving the same label to two instances that differ in some respects and responding to them nonverbally as if alike. For example, when a child first properly labels a larger round plastic object and a smaller round sponge object, ball, and treats them as play things to be rolled, bounced, etc., he has acquired the concept, ball, at an elementary level of psychological meaningfulness. Experiments in this project were not run to clarify these elementary processes. As noted in Figure S.1 the first three experiments were run to clarify the process of cognizing the definitional basis and structure of the concept population. The cognitive processes involved in acquiring more complex concepts and in extending the meanings of initial concepts are next outlined in some detail.

Analyzing the Situation.

Seventy-two, 80, and 80 subjects participated in three experiments designed to ascertain the effects of instructions as well as other variables in concept attainment. The optimal instructions in all three experiments were formulated to enable subjects to cognize the attributes of the concept population, to cognize the rule joining the attributes of specific concepts to be attained, and to draw correct inferences from "yes" and "no" instances which varied on only one attribute from the focus card. The stimulus materials in all three experiments were geometric forms varying on five bi-valued dimensions. In Experiment 1, the task consisted of identifying a two-attribute conjunctive concept from a series of six presentation slides. The optimal instructions facilitated performance. In Experiment 2 the same instructions and task were employed. The mean error scores for the two instruction groups were 1.99 and 3.21 for the optimal and minimal conditions respectively. The difference between these means was significant. Experiment 3 combined the instructional conditions of the previous experiments with the high- and low-frequency labels of Experiment 1. In addition, both conjunctive and disjunctive concepts were attained by each subject. Again, optimal instructions significantly facilitated concept attainment for both types of concepts. Thus, the processes were identified as associated with superior performance and the stated instructions for both types of concepts, and the stated instructions were comprehended and served as a cognitive control.

Securing Information

No experiment was undertaken in the present series to clarify this process configuration systematically. However, four main stimulus presentation methods were used in one or more of the experiments. First, a total stimulus array was presented simultaneously from which the subject selected instances. Second, only the instances necessary

to attain the concept were presented simultaneously. Third, instances were presented successively. Fourth, propositions combined with instances were presented successively.

In Project 1442 detailed information was obtained regarding selection strategies, with the emphasis on instance selection. Variants of a conservative focusing strategy were found to be the preferred strategy of subjects in experimental situations in which the structure of the concept population was presented in instructions and in which any one of a large unidentified number of possible concepts was to be attained. In the present series of experiments, the concentration was upon identification of the properties and rules carried by the instances.

Processing Information and Attaining the Concept

As noted in Figure S.1, six component processes are listed under the process configuration--Processing information regarding attributes and rules and attaining the concept. The next headings do not conform precisely to the component processes; rather they relate to the component process and the titles of the consecutive sets of related experiments dealing with the processes.

Hypothesizing Behavior. One hundred ninety-six, 204, and 160 adult subjects participated in three consecutive experiments designed to clarify hypothesizing behavior in concept learning. A hypothesis is the prediction of what the concept is and includes both the internal cognitive or mediating process and the observable response manifested as a result of that hypothesizing.

In experiment 4 the effects of two learning set orders were compared, subjects received 24 four-trial problems, 18 outcome and 6 nonoutcome problems. Nonoutcome problems were systematically interspersed with outcome problems. Based on analysis of the responses to the nonoutcome problems, the major conclusions were: (1) adult subjects offer hypotheses in a systematic predictable manner, apparently searching for the attribute that is the cue for correct responding; (2) certain attributes are initially hypothesized more frequently than others, apparently because of response sets, or preference for selecting certain attributes over others; (3) greater proficiency is attained on the first learning set than on the second; having tested and rejected a hypothesis during the first learning set, the probability is decreased that it will be retested.

In experiment 5 an attempt was made, using the same experimental materials and procedure, to ascertain the effects of preexperimental training on learning set. Based on the analysis of nonoutcome problems, the major conclusions were: (1) adult subjects offered hypotheses in a systematic predictable manner; (2) pretraining on a certain attribute increased the probability of that attribute being offered as the

hypothesis on the first experimental nonoutcome problem; however, an already established response set for the attribute, color, outweighed the effect of pretraining on the attribute, form.

In experiment 6 verbal material was used. The design was formulated to further clarify the effects noted in experiments 4 and 5. Based on the analysis of nonoutcome problems, the major conclusions were: (1) the pattern of hypothesizing behavior does not vary significantly as a result of which specific dimension is relevant; (2) a series of more than eight problems is required to establish a learning set (i.e., significant increase in the probability of hypothesizing a particular dimension); (3) development of a learning set increases the probability that the hypothesis relevant to it will be retested on subsequent problems; (4) pretraining effects are strong but transitory; that is, the small number of reinforcements on the pretraining problem increases the probability that the hypothesis will be subsequently offered, however, nonreinforcement of the pretraining hypothesis and reinforcement of another hypothesis is associated with rapid extinction of the pretraining hypothesis.

In these studies, the subjects offered hypotheses in a systematic predictable pattern, this being related to informative feedback provided by the experimenter. When a subject was told that a hypothesized value was correct, he maintained the hypothesis on subsequent trials. When told it was incorrect, he offered a different value. In addition, the subject tended not to offer the incorrect hypothesis until all other hypotheses had been offered or tested. This conclusion is probably the most significant of the entire set in this project, confirming many informal observations that human beings of various ages actively search in a systematic manner for cues that enable them to categorize instances as belonging or not belonging to a set. It is the defining attributes or values searched for, not the instances, that are critical. The instances only carry the essential information.

Memory. Forty-eight, 80, 48, and 80 students from introductory educational psychology classes participated in four consecutive experiments that were designed to ascertain whether certain stimulus variables and other conditions that supposedly impeded concept attainment because of increasing the memory load actually resulted in lower retention. Two stimulus variables manipulated in three of the four experiments were concept complexity--one or three relevant attributes comprising the concept, and method of presenting instances--simultaneous or successive presentation. The other variable manipulated in two of the four experiments was stimulus exposure time--5, 10, 15 seconds. Method of recall manipulated in two of the four experiments was unrestricted recall in which the subjects were to recall the instances and categories (whether the instance was or was not a member of the concept) in the order presented in the experiment, and random recall in which the subjects were to recall the instances and categories in a nonsequential random order fixed in advance by the experimenter. In the first three experiments the stimulus material consisted of four bivalued dimensions: shape (triangle or rectangle), number (one or two), color (red or blue), and size (large or small). In the fourth experiment two other dimensions were included: position (right or left)

and orientation of figures (upright or tilted). The dependent variables were concepts identified, values of instances recalled, and categories recalled.

The simultaneous method of presentation resulted in significantly better recall of instances and recall of categories in two of three and three of three experiments, respectively, as hypothesized. The unrestricted recall of instances and categories was significantly better in one of the two experiments and in the same hypothesized direction in the other. Stimulus exposure time of five seconds produced significantly poorer retention of instances and categories in two of two experiments as hypothesized. Complexity of the concept yielded mixed results in that in only one case was the three-relevant-attribute concept associated with significantly poorer recall. The other small differences generally were in the same hypothesized direction. The major contribution of these studies was to demonstrate for the first time that variables assumed to increase memory load, in fact, were associated with poorer retention scores. Moreover, the absolute level of recall under most conditions was sufficiently high to render questionable the limited memory assumption of various models of concept identification.

The results relating the same variables and conditions to concept attainment were less clear, although the tendency was in the hypothesized direction. Only the lower stimulus exposure time of 5 seconds, in comparison with 10 and 15, produced significantly poorer concept attainment in two of two experiments. Although the small differences in means were always in the hypothesized direction, the method of presentation did not produce significant differences in concept attainment and in only one of three experiments did concepts of one-attribute complexity result in higher attainment than concepts of three-attribute complexity. The method of recall was not expected to affect concept attainment, however this variable did affect concept identification in one experiment. The most plausible explanation of the lack of effect of both concept complexity and method of presentation on concept attainment is that the stimulus material of four bi-valued dimensions was too easy. However, this cannot be positively asserted.

Tests of memory were administered to subjects and related to concept attainment in two factor-analytic studies, reported later in more detail. In the first study, rote memory and span memory did not load on concept attainment factors. In the second study memory did load on concept attainment factors for low achievers but not for high achievers. Apparently memory is not a critical process in concept attainment when the concept population is simple, e.g., geometric forms of four bi-valued dimensions nor when the subject correctly categorizes instances on the basis of the relevant values. When the subject does not categorize the instances in more complex concept populations, the dimensions and values successively tested must be remembered as relatively discrete elements in order to eventually identify the values comprising the concept.

Cognitive Style and Limited Information Processing. Ninety, 80 and 256 subjects participated in three experiments which investigated the relationship between cognitive style, concept identification and limited information processing. In the last experiment, an additional purpose was to define cognitive style more precisely. In experiment 11, subjects were divided into three groups of 30 subjects on the basis of their scores on the Hidden Figures Test (HFT), which supposedly measures the degree to which subjects manifest an analytical or global cognitive style. Within each group of high-, medium-, and low-analytical subjects, the subjects were assigned to concept identification problems of either high complexity (five irrelevant bits of information), average complexity (three irrelevant bits), or low complexity (one irrelevant bit). The stimulus materials consisted of combinations of values from each of seven dimensions: letter (_H_ or _L_), number of letters (_one_ or _two_), size of letters (_large_ or _small_), color of letters (_red_ or _green_), orientation of letters (_upright_ or _tilted_), horizontal position of letters (_left_ or _right_), and vertical position of letters (_upper_ or _lower_). The subject's tasks were to correctly categorize stimulus patterns in terms of combinations of two relevant attributes. The dependent variable was number of error to a criterion of 16 consecutively correct responses. The results indicated that an individual's cognitive style did influence his concept identification performance. High-analytical subjects made fewer errors than the middle-analytical subjects who in turn made fewer errors than the low-analytical subjects. Concept identification was also an inverse linear function of concept complexity. The cognitive style of the subject did not interact with problem complexity.

In experiment 12, subjects were divided into two groups of high- and low-analytical ability on the basis of scores on the HFT. All subjects were given the high-complexity problems of experiment 11. Two types of training were given to independent subgroups of subjects. Subjects in the prompted-training condition received 24 trials on which the correct response button was indicated prior to their response. The subjects in the verbalization training condition were required to describe all of the values in each of the stimulus patterns before responding. A third condition was a combination of prompted and verbalization training. Finally, subjects in the control condition received no prompting or verbalization. Both the task and dependent variable were the same as for experiment 11. The results again showed that high-analytical subjects made fewer errors in concept identification than subjects of low-analytical ability. Both the prompt-only training and the verbal-only training conditions were superior to the control condition. However, the verbal-prompt group was no better than the control. Again, there was no interaction of cognitive style with type of training.

In experiment 13, the items of the HFT were analyzed to determine the factors which underlie performance on this cognitive style test. The ratio of relevant to irrelevant information was found to correlate well with item difficulty. From this it may be inferred

that attending to and discriminating between relevant and irrelevant characteristics, or features, of an entire stimulus situation are important components of cognitive style. Subjects were also given tests of limited information processing (TIPT) and concept identification (CLP). The TIPT yields three scores which indicate whether the subject, given two cards following the focus card, correctly classifies the last instance, or test instance, as belonging to the same concept as the focus card, as not belonging to the same concept, or as indeterminate membership for lack of sufficient information. The results indicated that analytical subjects were superior to nonanalytical subjects in the ability to process information and attain concepts.

Higher-Level Cognitive Processes From Factor-Analytic Studies. Two factor-analytic studies were carried out to clarify cognitive processes in concept learning. In the first study, experiment 14, geometric stimulus material was employed and the concepts to be attained were conjunctive of two or three values. The material was presented simultaneously. In one condition the subjects selected instances from an entire array and in the other condition only the instances needed to attain the concept were presented. Scores from 16 tests, two for each of eight abilities (General Reasoning, Verbal Comprehension, Induction, Deduction, Spatial Scanning, Perceptual Speed, Rote Memory, and Span Memory), and 18 scores from concept-attainment and limited information-processing tasks were obtained from each of 94 female subjects enrolled in educational psychology at the University of Wisconsin. The 34 task and ability variables were intercorrelated, then factored using Alpha factor analysis. The 12 Alpha factors were rotated to an oblique solution according to the Harris-Kaiser criterion. Seven of the eight hypothesized ability factors were identified, the only exception being Perceptual Speed. Five factors associated with the tasks were identified: three concept-attainment and two limited information-processing factors. The 12 factors were then correlated. General Reasoning, Induction, and Verbal Comprehension to a lesser extent, correlated positively with the three concept attainment factors. Equally important, Rote Memory, Span Memory, Spatial Scanning, and Deduction did not. It was hypothesized that the first three would be correlated with concept attainment in the selection condition but not in the minimum instance (presented) condition. Limited Information Processing (i.e., inferring whether instances belong to the same concept as the focus based on comparison of positive and negative instances) also exhibited low but positive correlations with concept attainment. As expected, the correlations of limited information processing with concept attainment were higher when only the minimum instances needed to attain the concept were presented than when the entire instance population was presented from which the subject selected instances.

In the second study, experiment 15, the stimulus material, other task conditions, and the ability tests varied from the preceding. Here, six consecutive propositions were presented in written form and each was followed with a written statement of a positive

instance of the concept to be attained, a negative instance, or both. After studying the proposition and instances, the subject sorted test instances as belonging or not belonging to the concept. At the end of each of the s' consecutive trials, a dependent measure was taken. Scores from 16 tests, two for each of eight abilities (Memory for Semantic Classes, Memory for Semantic Relations, Memory for Semantic Transformations, Induction, Syllogistic Reasoning, Cognition of Semantic Systems, Evaluation of Semantic Relations, and Cognition of Semantic Units), and six scores from different stages (trials) of the concept learning task were obtained from each of 102 female subjects enrolled in educational psychology at the University of Wisconsin. This total group was subsequently divided into two groups of higher achievers and lower achievers with Ns of 50 and 52. The division was based on the median number of errors on the sixth and last trial.

The derived orthogonal solution was obtained by Kaiser's normal varimax rotation procedures. Six interpreted and one uninterpretable factor were identified. The six interpreted factors were Meaningful Memory, Within-Task "Practice," Verbal Comprehension, Early-Task "Practice," Reasoning, and Logical Reasoning. Of particular interest were the other abilities associated with the task factors and the differences between higher achievers and lower achievers. The Within-Task factor showed significant loadings on all trials for higher achievers, for trials 3-6 for lower achievers. Memory test scores loaded on the Within-Task factor for the lower achievers but not for the higher achievers; whereas both inductive reasoning and cognizing semantic relations loaded on this factor for the higher achievers but not for the lower achievers. Thus, after the first trial, the higher achievers were already cognizing the relationships among the propositions, instances, and the concept. This did not occur systematically in the loadings until the third trial for the lower achievers. The lower achievers thus apparently had to memorize instances and propositions rather than cognizing relationships and drawing correct inferences concerning class membership. In the Early-Task Factor, which was the best indicator of efficient learning, Evaluating Semantic Relations loaded heavily for both groups, suggesting that of importance was not only cognizing the relations among propositions and instances, but also evaluating them on the basis of the defining properties of the concept. Memory for Semantic Relations loaded on the Early-Task Factor for the lower achievers but not for the higher achievers; whereas Inductive Reasoning loaded in this factor for the higher but not the lower achievers.

As noted, the stimulus material and the dependent measures varied markedly in the two experiments. The second set of material was designed as a model of difficult concept formation tasks appropriate for university students. In both experiments inductive reasoning loaded high on the concept attainment task. This apparently is related to the type of experimental arrangements which encouraged inductive rather than deductive reasoning. In experiment 15 cognizing semantic relations and evaluating semantic relations loaded on the concept learning task. Apparently the more difficult concept

in experiment 15 required higher-level abilities than did the less complex concepts of experiment 14. (Difficulty is controlled in the tasks used in experiment 14 by varying the rule, conjunctive or disjunctive, and the number of attributes defining the concept.) The vertical ordering of processes shown in Figure S.1 assumes that each process lower in the hierarchy is requisite for the one above it. The learning of principles, not dealt with in this project, is assumed to involve additional processes.

Process Configurations and Strategies

Now that the separate processes have been dealt with, the relationships between the process configurations require clarification. Concept learning is characterized by a moving back and forth between process configurations rather than by a unidirectional path. Nevertheless, observations of the performance of subjects, including their ability to follow instructions, suggests that the general direction is from left to right--analyzing the total stimulus array and its components, selecting instances as a means of identifying the attributes and rules that define the concept, and processing the potential information obtained.

Similarly, the processes which are listed vertically in the right column may sometimes occur in a different sequence. Thus, older subjects may possess a certain concept but need to acquire labels for its attributes or to discriminate additional attributes. While the preceding is noted, acquiring a concept involves all the processes from the sensing of external and internal stimulus situations through inferring the concept.

The preceding discussion suggests a broader concept of strategy than the four ideal selection strategies and the two ideal reception strategies proposed by Bruner. A concept-learning strategy, in view of the analysis thus far, is an information-processing strategy of which one component is selection. There are probably many variants, each variant somewhat dependent upon the specific characteristics of the concept population and also upon the relative emphasis required for each of the three process configurations.

Various elements of this approach to strategies were incorporated in instructions in the present series of experiments and in a prior series. A conservative focusing strategy had already been embodied in instructions and executed effectively by subjects as reported in Project 1442. Instructions to execute various elements of the process configurations were also developed and utilized successfully in the first three experiments and in experiment 12. The large remaining task is to devise instructions that will guide the process configuration outlined in the right column. At present more research must be done to clarify the role of memory and of the higher-level processes, particularly those associated with inductive and deductive reasoning.

Non-process Variables

Conclusions related to non-process variables were drawn, particularly in experiments 16 through 19. Each conclusion is stated succinctly and is followed with the number of the relevant experiment.

In addition to the major purpose of clarifying the operation of the component processes listed in Figure S.1, some of the 19 studies contained in this report had as a subsidiary goal the exploration of the effects of certain stimulus and subject variables in concept learning. A brief summary of these results follows.

Concepts defined by attributes joined disjunctively are more difficult to attain than concepts defined by attributes joined conjunctively. The mean percent of instances properly categorized as belonging to a disjunctive and a conjunctive concept were 90 and 68, respectively (experiment 3).

Concept attainment may be affected by response sets acquired by subjects prior to the experimental situation. Color hypotheses were offered more frequently than size, letter, or position hypotheses, although the difference was not statistically significant (4, 5, 6).

Concept complexity when defined by the number of irrelevant dimensions bears an inverse linear relation to performance in a concept identification task (11). The results for complexity when defined by the number of dimensions relevant to solution were equivocal. In experiment 7, the expected relationship was significant, that is, the lower the complexity the better the performance. However, in experiments 8 and 9 complexity did not influence performance. The reason for this discrepancy is not clear, however, it was suggested that the task used in these experiments was not sufficiently difficult at either level of complexity to allow consistent differences (across samples of subjects) to become apparent. In experiment 16, in which a slightly more difficult task was employed (five dimensions vs. four in experiments 7, 8, and 9) increasing the number of relevant dimensions did impede performance. However, this latter study employed younger subjects than the other experiments so no firm conclusion is warranted.

In experiment 12 the effects of three types of training on a concept identification task were contrasted. In the prompted-training condition, subjects were given 24 trials on which the correct response was indicated prior to their response. In the verbalization condition, subjects were required to describe all the values in each of the stimulus patterns before responding. A third condition was a combination of prompted and verbalization training. Both the prompt-only and the verbal-only training conditions were superior to the control (no training). The combined mean errors for the two training groups was 41.5, that for the

control 72.3. The group having both prompting and verbalization training made 61.8 errors on the average which was not significantly better than the control.

Two studies attempted to manipulate motivation through the use of monetary incentives (2, 16) in neither case was this an effective variable.

Socioeconomic status was found to be positively correlated with concept identification performance in experiment 16. Moreover, this relationship appeared to be independent of intelligence factors.

The ratio of positive to negative instances significantly influences concept formation in young children (17). Subjects receiving 100, 75, and 50 percent positive instances performed significantly better in acquisition than did subjects receiving only 25 percent positive instances. The latter group performed consistently below the chance level.

Finally the effects of type of material, figural or verbal, was examined in experiments 18 and 19. In experiment 18 geometric forms varying on a number of dimensions constituted the figural material. The verbal materials were formed by a direct translation of these perceptual attributes into the verbal labels (e.g., the word "red" for the color). In both cases, subjects attained two-value conjunctive concepts. The results indicated that the task was considerably easier when figural materials were used. The mean time-to-criterion for the figural materials was 16, that for their verbal equivalent was 25.

In experiment 19 the figural materials were H-patterns varying on several dimensions. The verbal materials were not simply the verbal labels for sensory dimensions, but were nouns which could be categorized on the basis of their associations with such labels (e.g., rabbit and bread can be categorized as soft-white; enamel and bone as hard-white). The subject's task in both conditions was to categorize instances correctly into four categories. Under these circumstances verbal materials led to more correct categorizations than did figural materials. It should be clear that there is no contradiction between the results of experiments 18 and 19 with regard to type of material. In fact, the two experiments really deal with different phenomena. The processes involved in attaining concepts with verbal materials which are labels for physical dimensions are probably quite different from those involved in attaining concepts based upon common associations among verbal units.

INTRODUCTION

In 1920, Hull demonstrated a reliable experimental technique for studying concept formation. However, from 1920 until 1950 relatively little attention was given by psychologists to the study of concept learning. A Study of Thinking by Bruner, Goodnow, and Austin (1956) generated widespread interest in concept learning by psychologists and educators. Many experiments have been reported in the last decade. Although the word Concept is now widely used, there is considerable disagreement among philosophers, psychologists, professors in subject fields, and educators regarding the nature of concepts (Klausmeier and Harris, 1966). In the present series of experiments, various populations of concepts were used. One main purpose of this introduction is to define Concept[1] so that the results of the experiments may be interpreted properly.

The present project was concerned with strategies and cognitive processes. In connection with concept learning, Bruner et al. (1956) used the term strategy to refer to a pattern of decisions in the acquisition, retention, and utilization of information that serves to meet certain objectives, i.e., to insure certain forms of outcome and to insure against certain others. In a similar but more detailed analysis of the structure of behavior, Miller, Galanter and Pribram (1960) designated control of behavior as Plan. They defined Plan as any hierarchical process in the organism that can control the order in which a sequence of operations is to be performed. They further indicated that a Plan might be differentiated into strategies, tactics, and eventually discrete TOTE units. Klausmeier, Harris, and Wiersma (1964) related strategies of learning to efficiency of concept attainment by individuals and groups. The second purpose of this introduction is to relate the preceding studies and the work of other investigators to the present project.

In a later section of the introduction are given the purposes of the project, an overview of the methods, and the timetable for gathering data during the three-year period. As may be noted in the table of contents, the report of each separate experiment, or series, treats purposes and methods as well as results.

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[1] The word referring to a Concept of concept will appear hereafter with the first letter in upper case and the entire word will be underlined.

The Nature of Concepts

Many people refer to a concept as an idea or abstraction and may, for clarification, give examples of concepts such as dog, numeral, fear, and motion. The widespread practice of defining concepts by giving synonyms and examples makesthis definition acceptable for general communication. However, if one wishes to study strategies in the learning of concepts, one defines concepts more precisely in terms of what is learned. Several attempts by scholars in the behavioral sciences and the academic disciplines to specify the more precise nature of concepts provide the background for the subsequent analysis of concepts.

Archer (1966), reflecting his psychological background, defined a concept as "the label of a set of things that have something in common" and then proceeded with a more precise definition by specifying the psychological properties of a concept. These are identifiability, learnability, labelability, transferability, and forgettability. Archer stated that, if a concept cannot be identified, it really does not exist. Archer then indicated that the concept can be learned, labeled, and forgotten, and that a concept once learned transfers or facilitates learning in other situations. These properties of a concept are inferred from experimental data. Archer's definition of a concept as "the label" is similar to Kendler's (1961): "a common response to dissimilar stimuli." Both definitions reflect the preference of associationist psychologists for staying close to the experimental data and defining what is learned in terms of observable behaviors, namely, words and other responses.

Bruner et al. (1956) reflected the viewpoint of cognitive psychologists and information theorists in referring to a concept as "a network of sign-significate inferences by which one goes beyond a set of observed criterial properties exhibited by an object or event to the class identity of the object or event in question, and thence to additional inferences about other unobserved properties of the object or event. We see an object that is red, shiny and roundish and infer that it is an apple; it is also edible, juicy, and will rot if left unrefrigerated, etc." The network, of course, is internal. Cognitive psychologists traditionally have seen a close relationship between observed structures and operations and the internal representations in the central nervous system. Some modern cognitivists discuss internal structures and processes in terms of computer terminology and cybernetic models. They also use more terms having less precise operational definitions, and correspondingly greater surplus meaning, than do the associationist psychologists.

Lovell (1966), a developmental cognitivist, made an important distinction between manipulative thinking and dialectical thinking. In manipulative, or logical, thinking concepts behave very much as objects do, for they have definitions, are treated as constant entities, and have their names manipulated. In dialectical thought, concepts serve as foci of organization in the continuous change or flow of thought. In manipulative thought, thinking is more abstract and dissociated from its immediate concrete context, whereas dialectical thought is inseparable from intuitive awareness.

Lovell then defined concept in terms of manipulative thinking, thus: "By concept we mean any term that can be recognized as a recurrent feature in an individual's thinking, provided the individual can go back over the mental actions from which the term was derived and anchor it in his experience of first-hand reality." He proposed that mathematical concepts represented in words such as _number_ and _place value_, are "terms that exist in thought indicating generalizations about systematic patterns of relations." Lovell reflected Piaget's tendency to explain internal processes semantically, based on observation and logical analysis of informal learning situations, rather than operationally, based on controlled experimentation.

Both Bruner and Lovell emphasized that the real concept is the internal representation of observable phenomena; Archer and Kendler, however, treated a concept as the response or label that can be directly observed. Equally important, all four psychologists emphasized the idiosyncratic nature of concepts, that is, a concept is what the individual possesses. Many nonpsychologists experience difficulty with the divergent approaches taken by associationists and cognitivists, or with the idiosyncratic emphasis, or with both.

Fehr (1966), a mathematician, stated that psychologists, not understanding the way the mathematician conceives mathematics, have contributed little toward understanding how mathematical concepts, such as _set_, _relation_, _equivalence_, and _fraction_, are learned. He perceived a mathematical concept as a form of mental construct, a very complex entity. Mathematical concepts, however, do not have readily specifiable attributes that are abstracted as common properties of otherwise dissimilar stimuli; rather they are defined in terms of axioms and logical relations by mathematicians. According to Fehr, children during elementary school years intuitively acquire only a first approximation of the real concept through experiences with exemplars and definitions. Thus, while a child properly associates the label "_fraction_" with some exemplars of fraction, he has not yet acquired the mathematical concept of fraction. Fehr is representative of other scholars who think of important segments of the total content as being embodied in concepts and who state that the true concepts are the definitions given by the experts, in this case, mathematicians.

Pella (1966) characterized three types of concepts in science. A _classificational_ concept is an abstraction from direct experience which groups together facts similar to one another. This type of concept facilitates description of phenomena. Examples of classificational concepts are found in words such as _vertebrate_, _tree_, and _air_. Thus, if an object or event manifests certain properties that are generally agreed upon by experts, then it can be classified as a vertebrate, tree, or air. For example, a vertebrate is an animal with a backbone and an internal skeleton. A _correlational_ concept is an abstraction from direct experience which correlates one fact with another. Examples of correlational concepts are embodied in the statements: "At sea level water changes to vapor at 212° F;" and "in an electrical circuit, current is inversely proportional to resistance, given constant voltage." This correlation permits

prediction of phenomena. A theoretical concept is an abstraction of a created idea which explains phenomena. An example of a theoretical concept is embodied in the statement that "light is an electromagnetic wave." This statement goes beyond sensory experience, but is congruent with human reasoning based on sensory experience.

The preceding discussion reveals substantial disagreement about the nature of concepts. This may be because concepts are very different according to subject fields. On the other hand, it may originate in the different frames of reference in which individuals perceive concepts. Lack of agreement probably stems from both factors, but might be resolved if Concept were defined in terms of properties just as one, dog, numeral candid, walking and many other concepts. Dog is defined as a domesticated, carnivorous mammal of the family Canidae. In turn the values of domesticated, carnivorous, mammal, and Canidae are specified. Fox is defined in terms of the same properties, except domesticated; however, the specific values of the properties differ from those of dog. Similarly Concept can best be defined as a product of learning, or more broadly experience, having properties of definability, structure, psychological meaningfulness, and utility.

In the discussion that follows what have here been referred to as properties of Concept will be referred to as characteristics in order to keep clear the distinction between the superordinate term Concept (that is, the concept of a concept) and specific concepts which are instances or exemplars. Another product of experience is factual information. Fact, too, has the same four characteristics as Concept but the values of the properties differ. Thus, as we can put dog and fox in the same category on the basis of certain properties and can further reliably discriminate between them, we can also reliably treat fact and Concept as of the same category but also as different in relation to the values of the four characteristics. In the next pages, each characteristic of Concept is dealt with in detail.

Definability

This characteristic refers specifically to the expert's definitions of the concepts in his area of specialty, or, more generally to definitions widely shared by individuals who speak the same language. As Carroll (1964) noted, words of a language can be treated as a series of spoken or written entities. The meaning of a word has both a denotative and a connotative aspect. The socially standardized, or denotative, meaning of the word corresponds to what is here designated the definability property of concepts. Carroll equated the denotative aspect with meaning and then indicated that the connotative meanings held by each individual were the individual's concept. For example, mother is the written entity; the societally accepted definition is the meaning; and we have general agreement on these. However, no one of us may have precisely the same concept of mother. In this report, the connotative meaning is treated as the idiosyncratic characteristic of Concept and is labeled psychological meaningfulness.

The definability characteristic of Concept represents the frame of reference from which many subject-matter specialists view the concepts in their field. When scholars say that the subject matter of the discipline is comprised mainly of concepts and statements of relationships among concepts, two assumptions are being made: first, the scholars can identify the concepts; and second, they can agree upon the definitions of the concepts. In connection with this property, the conciseness and basis of definition varies markedly across and within subject fields.

Many concepts are defined denotatively in terms of their discernible attributes. These attributes, abstracted as being alike in otherwise dissimilar objects, comprise the concept. For example, four attributes which allow some objects to be classified as oranges and others as lemons are size, color, shape, and taste. Similarly, the attributes useful in classifying some geometric forms as squares and others as equilateral triangles are number of sides and relative length of sides. Plants, animals, and many nonliving things have been studied by scientists and on the basis of observed attributes have been given names, assigned to classes, and organized into taxonomic systems; for example, the animal kingdom, the plant kingdom, the solar system, and the table of chemical elements.

Behavioral scientists frequently define the concepts of their field operationally. The properties of operationally defined concepts are inferred relationships rather than perceptible qualities or states. The most plausible explanation of this is that the events or states represented by concepts, such as learning, drive, and intelligence, cannot be observed directly. One operational definition previously given of Concept was "a common response to dissimilar stimuli." Another operational definition is contained in the statement: "Hunger drive is an internal condition of the animal expressed as a linear function of the amount of time elapsed since food intake."

In some subject-matter fields it appears that concepts are not defined in terms of perceptible or measurable attributes nor are they defined operationally. In mathematics, for example, concepts such as ratio and equivalence are defined by a statement of the relationship between two numbers or sets. In physics mass and rate are defined by the relationship between two other concepts. Some primitive concepts in the subject-matter fields may be left essentially undefined (cf. point, line, set, neutron, electron) and certain concepts may be defined in axioms and postulates (cf. parallel lines never meet). Here, then, the properties of the concept are the logical relations or axioms as specified by experts. It is possible that this type of concept is sufficiently different from others that the relations should not be treated as defining properties.

Deese (1967) emphasized the semantic properties of concepts. He reported a series of experiments in which linguistic change was induced, and he derived implications of the experimental results for the structure of meaning. Three aspects of meaning were noted: the concept itself; the phonemic and/or graphemic representation assigned to the concept; and the nature of events, relations, or objects

signified by the concepts. Deese pointed out that changes may and do occur in each of these aspects and in relationships among them. In connection with the latter, Deese noted that the concept of car and the graphemic representation of it have not changed in the past forty years, but the objects signified by car have. According to our definition of a concept, if the properties that define car have changed, the concept of car has also changed to the same extent.

Another point made by Deese was that many concepts used by Americans are not clearly defined. We are aware that frequently-used words such as style, class, reasoning, thought, fact, concept, democracy, and conservative, even when presented in context, do not elicit either the same responses or the same referents in well educated individuals, including the experts. Perusal of an unabridged dictionary shows that the socially prescribed definitions in many cases do not give the defining properties by which objects, events, and states can be precisely classified, or more broadly, by which relevant referents can be identified and related. Similarly, dictionaries, encyclopedias, and glossaries in many specialized fields do not indicate what the concept has in common with other concepts or by what properties it differs from others. Nevertheless, the vague meanings represented in synonyms, antonyms, and associative meanings derived from contextual clues are the only defining properties of many common concepts such as pretty, soul, and thinking.

We have seen, then, that one characteristic of Concept is definability. Concepts in the various disciplines as represented in words or other symbols, are defined in several ways: (1) observable or measurable attributes that inhere in objects, events, or states; (2) axiomatic and logical statements; (3) operationally identifiable relations among phenomena; and (4) synonyms, antonyms, and contextual meanings. These may be considered as types of concepts as well as different means of defining concepts.

Structure

A second characteristic of entities which may be put into the category, Concept, is structure. Concerning the structure of concepts, one considers the properties that comprise the concept, the rules by which the properties are joined, the form in which the concepts are represented, and the instances of the concept.

Properties, as noted before, may be attributes, semantic meanings, or axiomatic statements, depending upon the nature of th· concept. The number, relevance, and discriminability of properties comprising

concepts vary widely. The number of properties may vary from one to many: certain properties may be relevant and others irrelevant; and the properties may range from low to high discriminability in a sense modality. In general, as the number of relevant or irrelevant properties increases, and the discriminability between relevant and irrelevant properties decreases, concept attainment becomes more difficult.

Properties, in turn, may be examined on a molecular-molar continuum, in the sense of Guilford's (1967) structure of intellect. For example, think of the letters of the alphabet as units; of words like fish and fruit as representing classes; of words being joined into sentences by syntactical rules to express relations; and of relations being joined together in paragraphs to comprise systems that may be useful in describing, explaining, and the like. (Guilford uses the term classes to indicate concepts.) As we go higher up the scale from units, to classes, to relations, and systems, the concepts become more complex. In the Gagné hierarchy (1965) chains of concepts, or statements of relationships among concepts, are designated as principles; and relationships among principles are involved in problem solving. Correlation concepts as viewed by Pella and noted previously might be called principles. The associative law of addition in mathematics might also be called a principle rather than a concept. In view of the general acceptance of the above distinction between concepts and principles, the Gagné definition is acceptable; that is, a statement of relationship between concepts is classed as a principle.

Different rules for joining properties are illustrated in concepts represented by the words red, mammal, strike, and older. Red is a simple affirmation-type concept comprised of one property or dimension. Animals that simultaneously, or conjunctively, manifest three attributes--warm-blooded, mammary glands, live bearing--are classified as mammals. A strike in baseball represents a concept where attributes are joined by a disjunctive rule--and/or. A strike may be a ball thrown in the strike zone and called by the umpire, or it may be a pitch swung at and missed, or it may be a foul tip. A five-year-old child is older than one of four years, but younger than one of six. This is a relational-concept. Simple affirmation, conjunction, disjunction, and relation are not all the rules for joining attributes to form concepts and for joining simple concepts to form principles, nor is the applicability of the conjunctive, disjunctive, and relational rules to the various school subject matters fully established. In fact, conjunctive and disjunctive are types of relations.

The form in which concepts are represented is also an important component of structure. Some concepts may be represented in words or other symbols. Others may be represented in figural content. Some may also be experienced in feelings like anger, hate, or love. Guilford (1967) identified these as semantic, figural, and behavioral contents.

Instances of concepts range in inclusiveness from one to an indefinite number. The identity concept includes only one instance; there

is only one instance of each of us as a unique individual, different from every other individual. On the other hand there are countless grains of sand and blades of grass. Instances also vary in form, as do attributes. Instances of the same concept, for example, may exist in the natural world, directly available through one or more of the sense modalities, and these natural instances, in turn, may be represented in words or other symbols. Thus, both the actual objects--dogs, foxes, and wolves--and the words may serve as instances of canines. Further, when instances of concepts such as atom, time, and longitude are not directly available through a sense organ, nonverbal representations may be constructed that then become available.

In summary the structure of concepts is determined by the properties that comprise the concept, the rules for joining the properties, the form in which the attributes are represented, and the instances of the concept. Concepts comprised of one or two readily-discriminated properties with instances directly available to the senses are least complex and may be learned quite early in life. For example, the young child classifies objects, conditions, or events, such as ball, dog, alive, red, sleepy, and walking. Concepts for which there are no perceptible instances, comprised of several attributes joined by disjunctive rules or other relations that are not clearly defined and represented in words or other symbols are most complex and most difficult. Examples of relatively complex and difficult concepts are mass, force, motivation, thinking, infinity, electromagnetic waves, democracy, and religion.

Psychological meaningfulness

As noted previously, Bruner et al. (1956) have emphasized the idiosyncratic characteristic of Concept in their definition of Concept as a network of sign-significate inferences by which one goes beyond a set of observed criterial properties, etc. Also, S-R psychologists who accept the notion of mediation refer to Concept as the associative meanings, or implicit mediating responses, that the individual has formed between stimulus and response events whereby he treats otherwise dissimilar objects or events as belonging to the same class (Staats, 1968). Regardless of the definitional preference, it is apparent that individuals of the same age vary widely with respect to "the network of inferences," on the "implicit mediating responses" held regarding any concept. For example, concepts of reading, school, and time vary considerably among seven-year-olds as a result of differing environmental and biological factors. Similarly, there is great variability among graduate students in the level of comprehension of more complex but common concepts, such as grammar, culture, number, structure, liberal, style, and concept.

The concepts individuals possess also change with age, but more important, with increasing experience with the attributes, rules and instances. Consider your own concept of toy and food, now and when you were five years old. According to Inhelder and Piaget (1958), the changes that have occurred are qualitative; that is, at successive stages from infancy into adolescence roughly identified with years of age, distinct changes occur in the mental operations that individuals can perform.

Bruner (1966) suggested that the growing human being has three means of acting upon his environment: through direct action, through imagery, and through language. Individuals not only act upon the environment through these means but have appropriate internal counterparts in the central nervous system for representing sensory-motor acts, percepts, and thoughts. These internal representational schemes are designated enactive, ikonic, and symbolic. In early life the child apparently first acts upon objects, or manipulates them (enactive representation) before developing a mental image (ikonic) of them, and later associating names with them (symbolic). Although this sequence is typical of childhood and adolescence one continues throughout life to transact with the environment through action and imagery. However, with the development of language, one increasingly deals with his environment at the symbolic level. Bruner sees relatively more continuity in development and puts greater emphasis on environmental determinants of conceptualization than do Inhelder and Piaget.

In summary, from the phenomenological or individual point of view one's concepts change with increasing experience with the properties, rules, and instances and also with the qualitative development of conceptual processes. An adult's concept of space is quite different from what it was when he was ten and five years of age.

Recall now that some scholars perceive concepts solely as an important segment of the knowledge of the discipline, as defined by the experts. From this point of view only a very small proportion of the population possess any true concepts. The large proportion possess only approximations. Failure to observe the distinction between the phenomenological characteristic of Concept and the definability characteristic, the latter forming the bases for the scholar's Concept of a concept, has resulted in a serious lack of communication.

Utility

Of what value is it to have learned a concept? Bruner et al. (1956) have outlined five uses, or functions, of concepts as follows. First, concepts serve to reduce environmental complexity by allowing classification into superordinate categories. Second, concepts are means by which environmental objects and events are identified. Third, concepts reduce the necessity of continual relearning by providing easily recallable class labels. Fourth, concepts provide direction for instrumental activity. Fifth, concepts permit ordering and relating classes of objects and events.

Not all concepts are equally useful nor equally applicable to many situations. As mentioned in the discussion of structure, concepts can be ordered hierarchically according to the number and type of attributes that are joined, the rules for joining them, and the mode in which the concepts are represented. Higher order concepts function in more situations than those lower in the hierarchy. For example, the concepts of plant and animal function in more situations than do those of tree and bird.

To summarize this section, Concept was defined in terms of values along four dimensions or characteristics. This was necessary in order to facilitate the communication of the results of the present series of experiments. In these experiments populations of concepts were created or used that had finite numbers of attributes and specified rules for relating the attributes. This was essential so that the amount of information contained in the stimulus material could be controlled by the experimenters.

Also, in most of the experiments, the subjects already had made the essential discriminations to differentiate stimulus properties such as color, size, and shape. Therefore the subjects main task was to seek and subsequently identify the attributes and rule comprising the specific concepts they were to attain. This seeking for and identifying the attributes and rules in attaining the concept does not differ markedly from what students of any age do in forming concepts when they already have made the essential discriminations of instances and attribute properties and also possess the labels for the concept, instances, and attributes.

Assume, for example, that the student already has in his speaking vocabulary lime, shape, size, and color, and various properties of the latter three, such as round and oval, large and medium, orange and green. This student's task in classifying limes properly and identifying and giving a verbal definition of lime in terms of its properties and the related conjunctive rule--oval, medium-sized, and green--is similar to attaining such concepts as large red circles in the present series of experiments. Thus, the populations of concepts selected for these experiments were analogous to a large portion of concepts learned by children and youth. Already in kindergarten, children have acquired the labels and the discriminations for many of the concepts at the preliminary level at which they learn them. An individual who has not yet made the essential discriminations for the attributes and rules and has not associated the relevant labels with the properties faces an additional set of learning requirements for concept attainment. Thus, a young child for the first time in his life properly treats two objects of somewhat different appearance as belonging to the same class, ball. He has discriminated each and also categorized both properly. Sometime later when he labels the two balls correctly as ball, and then still later when he defines ball verbally in terms of its attributes, he will have had to acquire more labels and also to have discriminated the relevant attributes. The present experiments do not deal with these more elementary discriminating and labeling processes.

Strategies and Cognitive Processes

The processes of discrimination and of associating labels with objects and properties are not of primary concern in the present project. In recent years, however, psychologists have shown increasing interest in these and other mental processes involved in concept learning. Tasks have been devised which call for observable responses

from which, in turn, the mental processes may be inferred. Bruner, Goodnow, and Austin (1956), for example, constructed an array of 81 concept instances which represented all possible combinations of four trivalued attributes. The structure of a concept to be attained was described to the subject. A positive instance of the particular concept was pointed out. The subject then chose additional instances for testing to identify the critical attributes comprising the concept and was told, following each card choice, whether it was or was not an example of the concept to be attained. In addition, following each card choice the subject could offer a hypothesis concerning the nature of the concept. This type of task represents a selection paradigm. Bruner et al. also employed a somewhat different task in which the experimenter controlled the order of instance presentation; this represents a reception paradigm.

Bruner pointed out that a series of decisions are required in the selection paradigm--which instances and attributes pertaining thereto to test, which hypotheses to offer, and what changes to make when various contingencies are encountered. Regularities in decision-making are called strategies and provide the basis for making inferences about the mental processes involved in concept learning.

To analyze the decision-making process, Bruner formulated a set of ideal strategies which met certain objectives with "maximum rationality." The actual performance of the subject was then compared with these ideal strategies, and a best fit was determined. Four ideal strategies were identified under the selection paradigm: 1) Simultaneous Scanning - The subject initially entertains all possible hypotheses, and subsequently selects instances for testing on the basis of securing a maximum amount of information. After testing each instance, the subject deduces which hypotheses are still tenable and which have been eliminated; 2) Successive Scanning - The subject initially entertains a single hypothesis, and he chooses instances which will provide a direct test of that hypothesis; 3) Conservative Focusing - The subject holds no hypotheses initially. A positive instance is chosen as a focus, and each attribute of this focus is directly tested for relevance to the concept. This is accomplished by testing a sequence of instances, each differing from the focus in only one attribute value. When instances are tested in this manner, a "yes" indicates that the changed attribute is irrelevant to the concept and a "no" that it is relevant; 4) Focus Gambling - In this strategy, a variant of conservative focusing, the subject chooses a positive instance as a focus but then varies more than one attribute at a time. When instances are tested in this manner, a "yes" indicates that all changed attributes are irrelevant to the concept. A "no," on the other hand, provides no information concerning which of the changed attributes is relevant.

In addition to the four ideal strategies outlined under the selection paradigm, Bruner characterized two strategies which might occur in the reception paradigm: 1) Wholist - the subject initially adopts a hypothesis which consists in toto of the first positive

instance encountered. Subsequently, this hypothesis is revised by taking the intersect of the initial hypothesis and all other positive instances; 2) Partist - The subject entertains an initial hypothesis consisting of only part of the positive focus. If this hypothesis is disconfirmed by a subsequent instance, the subject formulates a new hypothesis consistent with all instances encountered.

Comparing actual sequences of responses with these ideal strategies, Bruner found a high degree of similarity which permitted him to characterize each sequence as representing a particular strategy. Further, varying task characteristics of information, memory load, and risk produced changes in the types of strategies employed. Bruner's techniques, then, attempted to externalize hypothesizing behavior for direct observation and evoked sequences of responses, permitting study of the interplay between successive responses.

In a subsequent study of selection strategies, Byers (1961) demonstrated that the simultaneous scanning strategy produced a sequence of card choices indistinguishable from that resulting from the conservative focusing strategy. Byers also pointed out that Bruner was not wholly objective in his method of characterizing a sequence of responses as a particular strategy. To circumvent these problems, Byers defined a general selection strategy in terms of the types of card choices (a) made by the subject.

Choices were characterized by the number of attributes on which they differed from the focus card (e.g., a_3 indicates the choice of a card differing from the focus on three attributes). Strategies were defined by various sets of these choice types. Strategy 1 (St_1) consisted of a_1; St_2 of a_1 and a_2; St_3 of a_1, a_2, and a_3 and so on. Thus, the strategies formed a continuum from homogeneous conservative focusing to heterogeneous focus gambling. To determine which strategy a subject had used on a given problem, a frequency distribution of types of card choices was made. The number of card choices consistent with each strategy was determined, and the probability of this consistency occurring by chance was ascertained. The strategy which yielded the smallest probability of chance occurence was designated as the strategy employed by the subject in attaining the concept. Byers' technique permitted objective identification of selection strategies.

In an empirical study of concept attainment, Byers found that practice modified the probability with which subjects used various strategies. In general, the probability of the conservative focusing strategy increased, while the probabilities of other strategies decreased. Also, the type of strategy employed had an influence on efficiency of performance, the most efficient performance being associated with the conservative focusing strategies.

Byers' (1961) study was the first in a series of studies at the University of Wisconsin. Klausmeier, Harris, and Wiersma (1964) also were unable to identify differences in the responses of subjects using simultaneous scanning and conservative focusing strategies.

The subjects used variants of conservative focusing and focus gambling strategies. This may have resulted because of the experimental materials and procedures which were similar to those of Byers (1961). In these experiments, stimulus display boards of 64 or 128 cards were used. In most experiments there were 6 bi-valued dimensions on a 64-card board and 7 bi-valued dimensions on a 128-cardboard. In the experiments the subject was not told the number of attributes comprising the concept he was to attain. On a 64-card board there are 728 possible concepts, using all 1-, 2-, 3-, 4-, 5-, and 6-value combinations, joined by a conjunctive rule. Naive subjects would not have been expected to know the total number of hypotheses without instruction on how to calculate the total, much less to store all the hypotheses in memory or to test them consecutively. Apparently Bruner's subjects were instructed concerning the structure of the specific concepts they were to attain, and the total number that might have been attained was necessarily small in order for any subject to employ a simultaneous scanning strategy.

The objective procedure for identifying the strategy used by subjects merits attention. After the subject had completed the task, identification of the strategy used when attaining a concept was made on two main bases. First, the initial hypothesis offered by the subject was checked to determine whether it was the correct concept. Each hypothesis offered by the subject was his statement of what he thought the concept was. Second, all the card choices made by the subject prior to his stating a first hypothesis were examined. The experimenter determined the number of attributes varied on each successive card choice from previous choices and the focus card, and also determined which attributes were varied. From this analysis, the amount of new information potentially yielded by each successive card choice was ascertained. If a card choice yielded information already potentially acquired by the subject, it was classified as a redundant choice.

On the basis of this analysis, the strategy of the subject was designated as one of three variants of a conservative focusing strategy--Ca, Cb, and Cc--or as one of two variants of a focus gambling strategy--Gh and Gi. The description of the strategies which follows shows that a strategy is a cognitive control by which the subject selects instances for testing and subsequently processes the obtained information. Table 0.1 summarizes the criterion behavior for classifying the five strategies and also the strategy characteristics.

1. Conservative Focusing Strategy (Ca). When using Ca, the subject checked each attribute to ascertain whether it defined the concept. From this we infer that he potentially cognized all the information essential to attain the concepts. He offered a first hypothesis which was the correct concept. From this we infer that he actually cognized all the essential information and he also combined the information about attributes and rule to arrive at the concept. He made redundant choices below the median number made by all subjects using Ca and Cb strategies. From this we infer that he used or remembered information better than did subjects making above the median number of redundant choices.

Table 0.1

Summary of the Strategy Identification System and the Characteristics of Strategies

Designation	Observable Criterion Behavior	Inferences Based on Knowledge Of Observable Behavior
Conservative Ca	Tested all attributes. Offered 1st hypothesis which was correct. Made below median number of redundant card choices.	Selected instances from a total array that contained the essential information, i.e., criterion attributes. Cognized the essential information. Remembered essential information. Made correct inference about attributes and rule.
Conservative Cb	Tested all attributes. Offered 1st hypothesis which was correct. Made above median number of redundant card choices.	Same as Ca, except in relation to above-median number of redundant choices. It is inferred from the above median number of choices that the subject intentionally retested more instances, or did not cognize potentially available information, or remembered information less well.
Conservative Cc	Tested all attributes. Offered 1st hypothesis which was incorrect.	Did not cognize potential information, or did not remember it, or made incorrect inferences.
Gambling Gh	Did not test all attributes. Offered 1st hypothesis which was correct.	Gambled successfully about nature of concept. Identified relevant attributes through any of three types of card choices. Selected essential information for relevant attributes. Cognized potential information. Remembered essential information. Made correct inferences.
Gambling Gi	Did not test all attributes. Offered 1st hypothesis which was incorrect.	Gambled unsuccessfully about nature of concept, or gambled successfully on nature of concept but did not select, cognize, or remember information, or did not draw correct inferences.

2. Conservative Strategy (Cb). The criteria for identifying Cb are the same as Ca, except that the number of redundant choices is above the median. The inferences drawn about Cb are the same as for Ca, except for those based on the above-median number of redundant card choices. On this basis we infer that the subject intentionally retested more of the same instance or instances containing equivalent information, or remembered information less well and therefore retested the same attributes, or did not cognize the potentially available information from earlier card choices.

3. Conservative Strategy (Cc). When using Cc, the subject tested each attribute, thus having all the necessary information potentially but, after doing so, offered an incorrect hypothesis. Apparently, the incorrect hypothesis resulted from one or a combination of the following: the subject made the card choices essential for securing the necessary information but did not cognize or forgot part of the information, or drew an incorrect inference relative to the criterial attributes and rule comprising the concept.

4. Gambling Strategy (Gh). When using Gh, the subject offered a first hypothesis which was the correct concept, without having checked all the attributes. In order to accomplish this, the subject gambled correctly that the concept was defined by a certain number of relevant attributes and a conjunctive rule. He was then able to identify the concept through any of three patterns of card choices: first, selecting "yes" cards which contained the attributes that defined the concept; second, selecting certain "no" cards from which the attributes that defined the concept could be inferred directly; and third, selecting some combination of "yes" and "no" cards which defined the concept but did not provide information about all attributes. In addition, one may infer that the subject, when using Gh, actually cognized the potential information from his card choices, remembered it, and drew the correct inferences from it.

5. Gambling Strategy (Gi). When using Gi, the subject offered a first hypothesis which was incorrect without having checked all the attributes. In contrast to a subject using the Gh strategy, he did not gamble correctly that the concept had a certain number of relevant attributes joined conjunctively; or, if he did so, he did not cognize the potential information, or did not remember it, or did not draw the correct inference.

The preceding strategies were based on analysis of the responses of hundreds of subjects. Subsequently, an attempt was made to instruct some subjects to use a conservative focusing strategy, and others, a focus gambling strategy (Klausmeier, Harris, and Wiersma, 1964). Subjects were readily taught to use the conservative focusing strategy and performed significantly better than those not instructed. Subjects could not be taught to use the focus gambling strategy consistently, that is, to vary two or more values from the focus. Consistent with the behavior of uninstructed subjects reported by Byers (1961), they tended to use a conservative focusing strategy after receiving "Not Correct" for early incorrect choices.

Subjects use complex strategies in attaining concepts. While it is possible to identify and label strategies, based on the patterns and accuracy of responses as shown in Table 0.1, the execution of a strategy involves a number of processes that one infers from the patterns of responses. A primary purpose of the present series of experiments was to deal explicitly with the processes that were inferred as shown in Table 0.1.

Purposes, Method, and Timetable of the Studies

The main objective was to clarify the processes involved in concept learning and to relate various non-process variables to efficiency of concept learning. The four specific questions stated in Proposal 2850 were as follows:

1. What are the cognitive processes involved in concept learning?

2. How do elements of information processing, such as cognizing information, remembering information, and hypothesizing solutions affect efficiency of concept learning?

3. How do elements of inferring, such as abstracting and generalizing, affect efficiency of concept learning?

4. What global strategies may account for the differences among individuals in efficiency of concept learning?

As the project progressed, major attention was given to operationally defining, based on controlled experiments and factor analytic studies, the subprocesses associated with three more global processes: (1) Cognizing the structure of the concept population, (2) selecting instances to identify the attributes and rules comprising the specific concepts to be attained, and (3) processing information to identify the attributes and rule comprising the specific concept. The major experimental effort was concentrated on a series of controlled experiments. Three experiments were designed to clarify cognizing the attributes of the concept population, cognizing the rule joining the attributes of the specific concepts to be attained, and inferring correctly from positive and negative instances of the concept. Three experiments were run to clarify the nature of hypothesizing behavior. The role of memory was studied in a series of four experiments. Cognitive style, which has implications both as a strategy and process, was studied in three experiments. A number of cognitive processes were related to performances in concept attainment in two factor analytic studies. Four exploratory studies were conducted at various times throughout the project to gain familiarity with one or more of the independent and dependent variables. The substantive area of the experiments, the time at which data were gathered, and the number of subjects in each study are reported in Table 0.2.

Table 0.2

Substantive Area, Period of Data Collection and Number of Subjects for Primary and Complementary Experiments

Experiment	Substantive Area	Data Collected	Number of Subjects
	The Effects of Instructions Designed to Clarify Cognitive Processes in Concept Attainment		
1	Instructions and Two Types of Labels	Sem. 2 1964-65	72
2	Instructions, Monetary Incentives, and Competition	Sem. 2 1964-65	80
3	Instructions, Sequence, Concept Type, and Test Item Type	Sem. 1 1965-66	80
	Hypothesizing Behavior in Concept Attainment		
4	Hypothesizing Behavior and Learning Set	Sem. 1 1965-66	196
5	Hypothesizing Behavior, Preexperimental Training, and Learning Set	Summer 1966	204
6	Hypothesizing Behavior, Length of Problem Sequence, and Preexperimental Training	Sem. 1 1967-68	160
	Retention and Concept Identification as Functions of Concept Complexity, Method of Presentation, Stimulus Exposure Time, and Conditions of Recall		
7	Concept Complexity and Method of Presentation	Sem. 1 1965-66	48
8	Concept Complexity, Method of Presentation, and Conditions of Recall	Summer 1966	80
9	Concept Complexity, Conditions of Recall, and Stimulus Exposure Time	Summer 1966	48
10	Method of Presentation, Stimulus Exposure Time, and Limited Memory Assumptions	Sem. 1 1966-67	80
	Cognitive Style, Concept Identification and Limited Information Processing		
11	Cognitive Style, Concept Complexity, and Problem Type	Sem. 2 1965-66	90
12	Cognitive Style, Prompted Training, Verbalization Training, and Problem Type	Sem. 1 1966-67	80
13	Cognitive Style and Limited Information Processing	Sem. 2 1966-67	256

Table 0.2 (Continued)

Experiment	Substantive Area	Data Collected	Number of Subjects
	Identification of Abilities in Concept Attainment Through Factor Analysis		
14	Relationship of Selected Cognitive Abilities to Concept Attainment and Limited Information Processing	Sem. 1 1964-65	94
15	Relationships Between Concept Learning and Selected Ability Test Variables	Sem. 2 1966-67	102
	Exploratory Studies of Relationships Among Variables		
16	Concept Complexity, Incentive, Social Class, and Concept Identification	Sem. 2 1965-66	180
17	Method of Presentation, Ratio of Positive to Negative Instances, and Concept Identification	Sem. 2 1965-66	80
18	Type of Material, Group Size and Concept Learning	Sem. 2 1964-65	96
19	Type of Material, Type of Classification and Concept Learning	Sem. 2 1966-67	36

In each experiment at least two non-process variables were manipulated in order to clarify a process more precisely in terms of its relation to a stimulus, organismic, or other variable. In a first attempt at categorizing the variables relevant to concept experimentation, 105 were identified and put into 5 sets: stimulus, instructions, response, organismic, and situational (Klausmeier, Davis, Ramsay, Fredrick, and Davies, 1966). The non-process variables that were manipulated, or used in stratifying, in the present experiments, were selected in terms of their potential robusticity.

In each subsequent report, more complete information is given regarding the independent and dependent variables, and also the purposes, subjects, experimental materials, and experimental procedures. Also, the results and a discussion were presented for each series or in some cases for separate studies.

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THE EFFECTS OF INSTRUCTIONS DESIGNED TO CLARIFY COGNITIVE

PROCESSES IN CONCEPT ATTAINMENT

Abstract

72, 80, and 80 subjects participated in three experiments designed to explore the effects of instructions as well as other variables in concept attainment. The optimal instructions in all three experiments were formulated to enable subjects to cognize the attributes of the concept population, to cognize the rule joining the attributes of specific concepts to be attained, and to draw correct inferences from "yes" and "no" instances which varied on only one attribute from the focus card. The stimulus materials in all three experiments were geometric forms varying on five bi-valued dimensions.

The design of experiment 1 was a 2 x 2 factorial combination of instructions (optimal and minimal) and type of concept label (high or low frequency). The task consisted of identifying a two-attribute conjunctive concept from a series of six presentation slides. The dependent variable was the number of errors made in classifying a series of 20 test instances as either exemplars or nonexemplars of the concept. The results indicated that optimal instructions and high frequency labels facilitated performance.

In experiment 2 the same instructions and task were employed. In addition, two levels of monetary incentive and high and low competition conditions were included. Thus the design was a 2 x 2 x 2 factorial.

The mean error scores for the two instruction groups were 1.99 and 3.21 for the optimal and minimal conditions respectively. The difference between these means was significant. The effects of the two levels of monetary incentive and the two levels of competition were not significant.

Experiment 3 combined the instructional conditions of the previous experiments with the high- and low-frequency labels of experiment 1. In addition, both conjunctive and disjunctive concepts were attained by each subject. Performance was analyzed in terms of the number of correct responses on four types of test items. Again, optimal instructions significantly facilitated concept attainment. The other major results were that conjunctive concepts were easier than disjunctive concepts and no significant difference in performance occurred as a function of high- and low-frequency labels.

THE EFFECTS OF INSTRUCTIONS DESIGNED TO CLARIFY COGNITIVE

PROCESSES IN CONCEPT ATTAINMENT[1]

The main purpose of this series of three experiments was to clarify two cognitive processes involved in concept learning. For this purpose optimal instructions were designed to enable the subject (a) to cognize the attributes structure of the concept population and (b) to draw correct inferences from the information presented on consecutive stimulus cards that either were or were not exemplars of the concept to be attained. Klausmeier, Harris, and Wiersma (1964); and Underwood and Richardson (1956) showed instructions to be an important facilitative factor in concept attainment but did not relate the content to cognitive processes. Underwood and Richardson (1956), however, showed that giving additional information about the concepts to be attained had a facilitating effect while Klausmeier et al. (1964) observed that instructions that outlined a strategy to be used in selecting attributes for testing had a facilitative effect.

In addition to exploring the effects of instructions, each of the following experiments had a secondary goal of ascertaining the effects of other variables such as motivation level, concept labels, and type of conceptual rules on concept identification.

Experiment 1: Instructions and Two Types of Labels

Purpose

In experiment 1, both optimal and minimal instructions were employed. A complete presentation of instructions is given in the method section, however, a brief description of the nature of the instructions may be helpful. According to Gagné (1965) instructions which fulfill the function of identifying the nature of the concept identification task to the subject must: (1) present the stimulus, (2) direct the attention and other activity of the learner, (3) provide a model for terminal performance, and (4) guide the direction of thinking. In the present experiment, a set of optimal instructions was designed which served these four functions. That is, subjects were presented with stimuli whose attributes and values were clearly described. This was designed to enable the subjects to cognize the attributes of the concept population. In addition, they were instructed

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[1]The present report is based on data collected by Wayne C. Fredrick (experiment 1) and on M.S. theses conducted by Patricia Kalish (experiment 2) and Daniel Lynch (experiment 3), during the academic year 1964-65, under the supervision of Herbert J. Klausmeier. The report was written by Elizabeth Schwenn and Herbert J. Klausmeier.

in how they might draw correct inferences about the concept from successive instances. Other subjects, however, received minimal instructions which served only to present the stimuli and draw attention to the various attributes comprising them. Nothing was said to the subjects receiving minimal instructions which might lead them to actively engage in such processes as stimulus selection, information processing, and retention which are thought to be of paramount importance in conceptual learning. If such active engagement is important for efficient concept identification, then one would expect subjects receiving optimal instructions to perform much better than subjects receiving minimal instructions.

In addition to instructions, the concept names or labels were manipulated in the present experiment. Previous research has indicated that labels meaningfully related to the stimuli or distinctive labels facilitate concept identification (Carey and Goss, 1957; Dietze, 1965). The influence of the frequency of verbal units employed as concept labels has not been investigated, however. One might expect more frequent labels (common words) to result in better performance than infrequent labels (nonsense syllables). It might also be the case that label frequency would have a differential effect depending upon instructional condition. That is, in the absence of instructions to obtain a concept, meaningful labels might help subjects recognize that stimuli could be grouped into concepts.

Subjects

The subjects were 72 students enrolled in an educational psychology class at the University of Wisconsin. Each subject was randomly assigned to one of four experimental treatments.

Experimental Materials

The materials included a slide projector, slides, screen, and booklets. The booklets contained instructions and an answer sheet. On the slides were geometric figures made up of five bi-valued attributes. The attributes were: (a) color (red or green), (b) shape (circle or square), (c) texture (plain or textured), (d) number of figures (one or two), and (e) size of figure (large or small). The concept that all groups had to attain was two textured figures. Six slides uniquely defined two textured. The first slide was a positive instance (focus card) and each remaining slide varied on only one attribute from the first slide. The slides and order of slides were the same for all four groups except for the label immediately beneath the geometric figure. The positive instances were labeled MAN for two groups and QJZ for the other two groups, and the negative examples were labeled NOT MAN and NOT QJZ for these same groups.

Experimental Procedure

The optimally instructed subjects read instructions concerning the nature of the concepts to be identified. The optimal instructions were as follows:

In this experiment you are going to identify concepts that I have in mind. A concept in this experiment is used to classify sets of cards into two groups, one set belongs to the concept and the other set does not. Let's clarify further how we are using the term concept in this experiment. Here is a card with one large textured green square. (Slide.) Suppose that I told you "yes," meaning the card belongs to the concept I have in mind. This would tell you that the concept I have in mind might be large square, or one large, or one textured, or green textured, or any other combination of features of the card. You would need more cards, however, to tell exactly what the concept is. Suppose I presented a second card that was identical to the first one except that it had one small textured green square, instead of one large textured green square. If I told you "no," meaning this card does not belong to the concept, you could infer that all cards that are small do not belong to the concept. The third card I present might be identical to the first one except that it contained a circle instead of a square. I might tell you "yes" meaning it does belong to the concept. You would know that both circles and squares belong to the concept. Still other cards would be needed to tell exactly what the concept is. Thus, concepts in this experiment are combinations of the features of the cards and are used to classify sets of cards. After seeing a series of cards you can decide what the concept is; you can tell which cards do and do not belong to the concept. The label below each card will tell you which are in the concept.

All subjects in both the optimal and minimal instruction groups were told the following before beginning the task.

You are going to see slides which have geometric figures on them. Some of these figures will be circles and some will be squares. The figures can be large or small, red or green, solid or textured. There can either be one circle or two circles, or one square or two squares on a slide. For example, look at this slide. (Slide.) We could describe it as two, large, plain, green, square, figures. Now will you please describe the next figure.

Write description here:

We will show you a series of six slides. Please watch closely. We will ask you questions about them. Do not write; do not turn page now.

All subjects were first allowed to read the appropriate instructions. The series of six labeled slides was then shown at the rate of 20 seconds per slide. Twenty test instances (not labeled) were

presented two per slide at the rate of 10 seconds per slide. Subjects were to mark on their answer sheets the instances that would be labeled MAN (QJZ).

Experimental Design

The design was a 2 x 2 factorial with 18 subjects per group. The factors were instructions (optimal or minimal) and labels (word or trigram).

Results and Discussion

Of the test instances, seven were positive examples of the concept and 13 were negative. Three error measures were obtained for each subject: (a) the number of positive examples not marked (exclusion errors), (b) the number of negative examples marked (inclusion errors), and (c) the total number of errors. These measures were analyzed by separate two-way analyses of variance.

Table 1.1 shows the number of exclusion, inclusion, and total errors made by each group. The analysis of the inclusion errors showed

Table 1.1

Errors Made by the Four Experimental Groups in Experiment 1

Instructions	Label Frequency	Exclusion	Inclusion	Total
Optimal	High	16	17	33
Optimal	Low	22	48	70
Minimal	High	36	37	73
Minimal	Low	90	28	118

no significant effects from either labels or instructions. The analysis of exclusion errors showed both instructions (F = 32.0, df = 1/68, $p < .01$) and labels (F = 17.0, df = 1/68, $p < .01$) to be significant. These main effects were also present in the total errors; the F for instructions was 17.0; that for labels was 19.6. Thus when exclusion and total errors are considered, subjects receiving optimal instructions perform better than subjects receiving minimal instructions. Also, subjects receiving high-frequency labels categorized test instances better than subjects receiving low-frequency labels.

Of interest are the interactions of labels and instructions which appeared in the analyses of the exclusion and inclusion errors. For the exclusion errors, the F for the interactions was 9.6 (df = 1/68, $p < .01$); for the inclusion errors the F value was 4.5 ($p < .05$). By making individual comparisons of means, it was found that the group receiving optimal instructions and low-frequency labels made significantly more inclusion errors ($p < .05$) than the group with optimal

instructions and high-frequency labels. The group receiving minimal instructions and low-frequency labels made significantly more exclusion errors ($p < .01$) than each of the other three groups. The inclusion error interaction suggests that the instructions had instilled in optimally instructed subjects with low-frequency labels a "set" to consider some of the test instances to be examples of the concept, but the low-frequency label caused them to do this categorizing less efficiently than when the high-frequency label was present. The exclusion error interaction suggests that the minimally instructed, low-frequency label group reacted to the situation very differently from the other three groups. Not only did this group make significantly more exclusion errors than the other groups, but it was the only group to make more exclusion errors than chance would predict. A X^2 of the 90 observed errors compared to the 63 errors expected by chance was large and significant ($X^2 = 23$, $p < .001$). It appears that the subjects receiving minimal instructions along with low-frequency labels were not prepared to accept very many of the test instances as belonging to the concept, and, in fact, were systematically biased against doing so. The large proportion of exclusion errors to inclusion errors would suggest that this group was generally inclined to say no to the test items; this inclination would be true to form if it is assumed the group was not viewing the task conceptually. The other three groups, however, were apparently dealing with the task conceptually; they were able to correctly categorize from 71 to 87 per cent of the positive instances. This is a high figure compared to the 29 per cent scored by subjects in the minimal instructions, low-frequency label group.

The conclusion resulting from this experiment is that the subject needs to recognize the conceptual nature of the task so that the concept can be learned efficiently. The presentation of instances without either instructions or meaningful labels or both was not a sufficient condition to produce concept learning in the present situation.

Experiment 2: Instructions, Monetary Incentives, and Competition

Purpose

The major purpose of experiment 2 was to replicate the optimal and minimal instructional conditions of experiment 1. Since the motivational state of the subject is also assumed to be associated with efficiency of concept attainment, a second purpose of this experiment was to assess the effects of two levels of monetary incentive on concept attainment. Although an extensive number of experiments have investigated the effects of monetary incentives on human learning and performance, few studies have been concerned with the effects of monetary incentives on concept attainment.

A third variable, competition, was also investigated in the present experiment. Research on competition has generally centered on comparing the effects of competition and cooperation on a variety of tasks. Little work has been done comparing the effects of competition and noncompetition, and no studies were found which investigated the effects of

competition on concept attainment. The present study sought to fill this gap by comparing the effects of high and low competition on a concept attainment task.

Subjects

The subjects were 80 paid volunteers drawn from two beginning courses in educational psychology at the University of Wisconsin. Seventy-two females and eight males participated in the experiment. The median age of the subjects was 22.

Experimental Materials

The stimulus materials were the same geometric forms used in experiment 1. There were two series of six slides each which uniquely defined two-attribute conjunctive concepts (red circle; two textured). Positive instances were labeled YES and negative instances were labeled NO. The last 10 slides of both series each contained two test items. The test items following the concept red circle consisted of six positive and 14 negative instances of that concept. The test items following the concept two textured consisted of seven positive and 13 negative instances of that concept. The instances on the test series were, of course, unlabeled and had not been shown in the presentation series.

A three-page booklet consisting of task instructions and response sheets were also used.

Experimental Procedure

Four sets of instructions were used. The non-competitive, low-incentive instructions informed the subjects that they would be shown two series of slides, and following each series they would be asked questions about the slides. The amount of money earned by each subject depended only on his score and ranged from $1.25 for those answering 80 per cent of the questions correctly to $0.25 for those answering 20 per cent of the questions correctly. Thus it was possible for each subject to receive $1.25.

The subjects in the competitive, low-incentive condition were told that they would be shown two series of slides, and following each series they would be asked questions about the slides. The amount of money earned by each subject depended on his score in relation to the rest of the group. Each subject received a different amount of money, ranging from $1.25 for the highest score to $0.25 for the lowest score.

Subjects in the high-incentive conditions received similar instructions except that the amounts of money were doubled.

Two sets of task instructions were used. The optimal and minimal instructions were the same as those used in experiment 1. Each subject solved two conjunctive concepts. The method and rates of presentation of the slides were as in experiment 1.

Experimental Design

There were eight treatment combinations formed by the three two-level variables (optimal and minimal instructions, high and low incentives, high and low competition), and a 2 x 2 Latin square was replicated five times under each treatment condition. Ordinal position and sequence effects were balanced within the Latin square. There were five subjects tested in each of the 16 sequence-instruction-motivation-competition cells.

The measurement of the subjects' performance was number of errors of which there were two types: errors of exclusion (not choosing positive instances of the concepts), and errors of inclusion (choosing negative instances of the concepts).

Results

An analysis of variance of the subjects' scores based on number of errors yielded statistically significant effects of instructions ($F = 4.63$, $df = 1/64$, $p < .05$), ordinal position in sequence ($F = 5.22$, $df = 1/128$, $p < .05$), and type of error ($F = 5.35$, $df = 1/64$, $p < .05$). The main effects of level of monetary incentive, level of competition, sequence of concepts, and type of concept were not statistically significant.

The mean error scores for the two instruction groups were 1.99 and 3.21 for the optimal and minimal conditions respectively. Subjects in the optimal instructions condition tended to obtain lower error scores than subjects in the minimal instructions condition. It appears that presenting information about the nature of the concept whereby the subject cognizes the attribute structure of the concept population and draws correct inferences from successive positive and negative exemplars facilitates performance. It should be noted that there was no significant instruction by type of error interaction which indicated that instructions did not have any differential effect on the type of errors committed. There was also no instruction by order interaction, indicating that the effect of instructions persisted beyond the first concept and was not diminished by the practice effect of attaining a first concept.

Subjects tended to obtain higher mean error scores on the first concept than on the second. The means were 3.30 and 1.90 respectively. This probably indicates that performance on the first task had a positive transfer effect on the second task, even though the subjects received no feedback on the quality of their performance.

Subjects, on the average, made more errors of inclusion (3.13) than errors of exclusion (2.08). This is likely to be due to the fact that there were more opportunities for subjects to make errors of commission than errors of omission.

Discussion

The findings of the present study indicate that subjects who receive information about the attribute structure of concepts to be attained, and about the inferences to be drawn from positive and negative exemplars, obtain significantly lower error scores than subjects who do not receive this information. This finding, of course, corresponds to the results of experiment 1.

The performance of subjects under the different incentive condition did not differ. This finding, which corresponds to the results of Miller and Estes (1961) in discrimination learning and Kausler and Trapp (1962) in serial learning, indicates that various levels of monetary incentives, at least as these levels were defined in the present experiment, do not differentially affect concept attainment.

No difference was found in the present study as a result of the high- and low-competitive conditions. This result tends to support the notion of Miller and Hamblin (1963) that competition does not affect performance on tasks in which success does not require interaction with other subjects. The generality of the present finding should not be emphasized, however, since it may have been the case that the competitive instructions were not sufficiently intense to either inhibit or facilitate performance.

Experiment 3: Instructions, Sequence, Concept Type and Test Item Type

Purpose

This third experiment repeated the optimal and minimal instructional conditions of experiments 1 and 2. In addition, high- and low-frequency labels were employed as in experiment 1 to see if that effect was replicable.

The effectiveness of instructions and labels might vary as a function of the type of concept to be attained. To test this possibility, both conjunctive and disjunctive concepts were employed.

Subjects

The subjects were 80 students in an educational psychology course at the University of Wisconsin. Fourteen of these were male and 66 were female. The proportion of males to females was kept the same for all groups.

Experimental Materials

The stimulus materials consisted of the same geometric forms used in experiments 1 and 2. A tape recorder was used to control the slide projector and to give procedural instructions such as "turn the page." Booklets were used to present different sets of instructions and to provide response sheets.

For the conjunctive concepts, six slides were used to uniquely define each of the two-attribute concepts (two-textured and small-green). For each of the two two-attribute disjunctive concepts (red or square and one or circle), seven slides were used. For all concepts the first slide was a positive instance (focus card). For the conjunctive concepts, each remaining slide varied on only one dimension from the first slide. Because disjunctive concepts are difficult for subjects and because the experimenter wanted the subjects to perform above chance level, a presentation order was chosen for each disjunctive concept that, it was hoped, would facilitate learning.

Experimental Procedure

The minimally instructed subjects read irrelevant material while the optimally instructed subjects read instructions concerning the nature of the concepts to be identified. The optimal instructions for conjunctive concepts were identical to those in experiments 1 and 2 except that specific instructions regarding the nature of conjunctive concepts were added as follows:

> Your first two tasks will involve identifying "conjunctive" combinations of features. In such a concept the features that are combined to form the concept must all be present for a card to be a member of the concept.

The optimal instructions for the disjunctive concepts were:

> In this experiment you are going to identify concepts that I have in mind. A concept in this experiment is used to classify sets of cards into two groups, one set belongs to the concept and the other set does not. Let's clarify further how we are using the term "concept" in this experiment. There is a card with one large textured green square. Suppose that I told you "yes," meaning the card belongs to the concept I have in mind. This would tell you that the concept I have in mind might be any possible combination of the features of the card.
>
> Your first two tasks will involve identifying "disjunctive" combinations of features. In such a concept, only one of the features from the combination of features must be present for the card to be a member of the concept. For example, if the concept were large or green, it would mean that all cards containing large figures, all cards containing green figures, and of course all cards containing figures that were both large and green would be examples of the concept.

All subjects in both the optimal and minimal instruction groups were told the following just before beginning this task.

> You are going to see slides which have geometric figures on them. Some of these figures will be circles and some will be squares. The figures can be large or small, red or green,

solid or textured. There can be either one circle or two circles, or one square or two squares on a slide. The slide you are looking at is an example. It is described as one, large, textured, green, square figure. When it appears that everyone is finished reading these instructions, another slide will be shown for you to describe.

Write description here:

All subjects were given two conjunctive and two disjunctive concepts to solve. The first conjunctive concept (C_1) was two textured; the second (C_2) was small green. The first disjunctive concept (D_1) was red and/or square. The second (D_2) was one and/or circle. The two sequences were C_1 C_2 D_1 D_2 (Sequence I) and D_1 D_2 C_1 C_2 (Sequence II).

High- and low-frequency labels were used on the presentation slides beneath the instances. A subject saw only one type of label. The labels for each concept were as follows: MAN and ZGJ for the two textured; PLACE and XFQ for the concept small green; YEAR and QJH for the concept red and/or square; HAND and XZF for the concept one and/or circle. An instance that was a member of the concept included the noun or consonant label while a nonmember included the label and the word NOT before it. The high-frequency labels were chosen from Part IV of Thorndike and Lorge lists (1944) on the basis of being one-syllable nouns of very high occurrence. The low-frequency labels were taken from a list of consonant triads compiled by Underwood and Schulz (1960).

The presentation slides for each concept were followed by 16 slides containing 32 test items. The 32 test items were the instances that resulted from all the combinations of the five dichotomous dimensions. Consequently, for each conjunctive concept, six of the 32 test items had been shown previously in presenting the concept. For each disjunctive concept, seven test items had been shown previously. These repeated items were randomly distributed throughout the other test items. The test items were of four equally occurring types: (1) those test items containing both relevant attributes of the concept (Item Type I); (2) those items containing only one relevant attribute of the concept (Item Type II); (3) those containing the other relevant attribute of the concept (Item Type III); and (4) those containing neither relevant attribute (Item Type IV). The test items were presented in random order. The subject's task was to decide for each test item whether it would be a member or nonmember of the concept.

Experimental Design

The design was 2 x 2 x 2 x 2 x 4 with repeated measures across two variables having two and four levels respectively. The three variables without repeated measures were instructions (optimal and minimal), labels (high and low frequency), and sequence (I and II). The two variables for which each subject received all treatment levels were concept type (conjunctive and disjunctive) and test item type (Types I, II, III, and IV). Ten subjects were used in each cell of this design.

Results

The dependent variable was the number of test items correct. For each subject the scores for the two conjunctive concepts were combined as were the scores for the two disjunctive concepts. Thus, for each test item type within a type of concept the scores ranged from zero to 16. Summing over test items, then, a total score of 64 per subject per concept type was possible.

Table 3.1 contains the mean number of correct responses and the standard deviations for the main effects found to be significant along with the single significant first-order interaction.

Table 3.1

Means and Standard Deviations of the Significant Main Effects and First Order Interaction in Experiment 3

Effect	M	SD
Instructions		
Optimal	100.01	30.08
Minimal	88.82	34.58
Concept Type		
Conjunctive	53.52	14.68
Disjunctive	40.94	15.71
Test Item Type		
I	24.81	7.16
II	22.64	8.64
III	21.90	8.58
IV	25.11	7.54
Sequence x Concept Type		
Conjunctive, Sequence I	55.25	15.86
Conjunctive, Sequence II	51.80	13.44
Disjunctive, Sequence I	38.83	16.32
Disjunctive, Sequence II	43.05	15.05

Note: The probability of a correct response on the basis of chance was .50 under all conditions.

Significant main effects were found for instructions ($\underline{F} = 12.10$, $\underline{df} = 1/72$, $\underline{p} < .001$), concept type ($\underline{F} = 65.09$, $\underline{df} = 1/72$, $\underline{p} < .001$), and test item type ($\underline{F} = 11.04$, $\underline{df} = 3/216$, $\underline{p} < .001$). There were no significant main effects due to either sequence ($\underline{F} < 1$) or labels ($\underline{F} < 1$). There was a significant interaction of sequence and concept type ($\underline{F} = 6.05$, $\underline{df} = 1/72$, $\underline{p} < .05$).

Table 3.1 shows that subjects fully instructed about the nature of the concepts performed significantly better than subjects receiving minimal instructions designed only to acquaint them with the stimulus material. The effect of concept type was, as expected, that subjects did better on conjunctive than on disjunctive concepts. Test item Types I and IV were easier for subjects than item Types II and III. A Sheffe post-hoc means comparison showed the difference between these two pairs of means to be significant ($p < .01$). In the sequence by concept type interaction, subjects identified conjunctive concepts first in Sequence I and disjunctive first in Sequence II. Negative transfer occurred in both cases. Conjunctive concepts were identified better if they occurred before rather than after disjunctive concepts. Similarly, disjunctive concepts were identified better if they occurred before rather than after conjunctive concepts.

In addition to the significant findings reported above, the following second-order interactions were significant: (a) sequence x labels x concept type ($F = 7.20$, $df = 1/72$, $p < .01$), (b) instructions x sequence x test item type ($F = 6.47$, $df = 3/212$, $p < .001$), (c) instructions x concept type x test item type ($F = 3.71$, $df = 3/216$, $p < .025$).

In the interaction of sequence, labels, and concept type, performance was better on a concept type with high-frequency labels when that type occurred as the first concept type encountered by subjects. When the concept type was the second encountered by the subjects, performance was better under the low-frequency label condition.

Although the main effect of test item type was not confounded, the two interactions involving this factor may well be. This is because presentation instances were also used as test instances randomly distributed throughout the other test items. Some test items (notably those of Type IV) occurred with varying frequencies during presentation. As a result it is probable that both second-order interactions involving test item type and instructions were generated by attempts of uninstructed subjects to memorize previously presented cards. This notion is supported by the fact that in both interactions most of the variance was contributed by item Type IV. The number of presentation instances of this type varied more across concept types than did the other test item types (from zero on the conjunctive concepts to four on the second disjunctive concept). Thus, the amount of prior training on another type of concept, the amount of presentations given a particular item type and the amount of instruction are inextricably related in these interactions.

Discussion

Subjects instructed about the attributes and rules comprising the concepts to be attained and also about drawing inferences from positive and negative instances following the focus card performed significantly better than subjects not so instructed. This agrees with the results obtained in experiments 1 and 2, and by Klausmeier, Harris and Wiersma (1964). The subjects performed selection tasks in the Klausmeier et al. study and reception tasks in the present three experiments, Thus,

performance improved with appropriate instructions in both types of tasks. Again, the optimal instructions were designed to cognize the attributes of the concept population and to cognize the attribute and rule structure of the specific concepts to be attained. Also, the optimal instructions were formulated to enable the subjects to draw correct inferences from successive positive and negative instances. The minimal instructions did not actively engage the subjects in these processes.

The effectiveness of the optimal instructions did not differ as a function of the type of concept. However, as has been found previously (Bruner, Goodnow and Austin, 1956) disjunctive concepts were more difficult than conjunctive concepts.

The frequency or meaningfulness of verbal units used as labels did not, as in experiment 1, have an effect on concept identification. Nor, as might have been expected, did label frequency have a differential effect upon instructed and uninstructed subjects. However, label frequency was not totally without effect as can be seen from the significant interaction of sequence, labels, and concept type. Why high-frequency labels should have a facilitative effect when the concept occurs without previous training and why low-frequency labels have a facilitative effect when prior training has occurred on a different concept type is not clear. Perhaps the high-frequency labels serve as a distractor after the subject has experience with the task.

The sequence effect was not significant, indicating no difference in performance between a conjunctive-disjunctive sequence and a disjunctive-conjunctive sequence. This is in agreement with the findings of Conant and Trabasso (1964). However, the sequence by concept type interaction found in the present study differs from Conant and Trabasso's results in that they found no transfer effect related to type of concept. The interaction of sequence and concept type in the present study indicates negative transfer. Performance was poorer on either concept type when it followed the other than when it preceded the other.

Test items containing both or neither relevant attributes (Types I and IV) were easier to identify than test items containing only one relevant attribute (Types II and III). This result agrees with an analysis of the facilitative effect of redundant relevant information reported by Bourne (1966).

To reiterate briefly, the finding of major significance in all three experiments was that instructions is a powerful variable influencing concept attainment. When subjects are given instructions which lead them to cognize the attributes of a concept population and to cognize the rule structure of the specific concepts to be attained, then the performance of these subjects is greatly facilitated.

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HYPOTHESIZING BEHAVIOR IN CONCEPT ATTAINMENT

Abstract

196, 204, and 160 subjects participated in three consecutive experiments designed to clarify hypothesizing behavior in concept learning. A hypothesis is the prediction of what the concept is and includes both the internal cognitive or mediating process and the observable response manifested as a result of that hypothesizing.

In experiment 4 the effects of two learning set orders were compared, subjects received 24 four-trial problems, 18 outcome and six nonoutcome problems. Nonoutcome problems were systematically interspersed with outcome problems. Based on analysis of the responses to the nonoutcome problems, the major conclusions were: (1) adult subjects offer hypotheses in a systematic predictable manner, apparently searching for the attribute that is the cue for correct responding; (2) certain attributes are initially hypothesized more frequently than others, apparently because of response sets, or preference for selecting certain attributes over others; (3) greater proficiency is attained on the first learning set than on the second; having tested and rejected a hypothesis during the first learning set, the probability is decreased that it will be retested.

In experiment 5 an attempt was made, using the same experimental material and procedures, to ascertain the effects of preexperimental training on learning set. Based on the analysis of nonoutcome problems, the major conclusions were: (1) adult subjects offered hypotheses in a systematic predictable manner; (2) pretraining on a certain attribute increased the probability of that attribute being offered as the hypothesis on the first experimental nonoutcome problem; however, an already established response set for the attribute, color, outweighed the effect of pretraining on the attribute, form.

In experiment 6 verbal material was used. The design was formulated to further clarify the effects noted in experiments 4 and 5. Based on the analysis of nonoutcome problems, the major conclusions were: (1) the pattern of hypothesizing behavior does not vary significantly as a result of which specific dimension is relevant; (2) a series of more than eight problems is required to establish a learning set (i.e., significant increase in the probability of hypothesizing a particular dimension); (3) development of a learning set increases the probability that the hypothesis relevant to it will be retested on subsequent problems; (4) pretraining effects are strong but transitory; that is, the small number of reinforcements on the pretraining problem increases the probability that the hypothesis will be subsequently offered; however, nonreinforcement of the pretraining hypothesis and reinforcement of another hypothesis is associated with rapid extinction of the pretraining hypothesis.

HYPOTHESIZING BEHAVIOR IN CONCEPT ATTAINMENT

A hypothesis in a concept identification experiment may be defined as the subject's prediction of the correct basis for responding. The subject predicts the single value of a dimension, or the combination of values of one or more dimensions in the case of a multi-attribute concept, that he thinks the experimenter has selected as the concept to be attained. A subject's hypotheses may be inferred from his verbal statements or observable responses during concept attainment. The term "hypothesizing behavior" includes both the internal cognitive process of hypothesizing and the observable responses manifested as a result of that hypothesizing. Levine (1963) stated that hypothesizing (i.e., at the outset of a concept attainment experiment, predicting the cues or other properties to identify the concept) is the most important mediating process available to the adult human subject.

Hypothesizing behavior is only one of a larger set of processes involved in attaining a concept. Some psychologists prefer to use information-processing terminology closely allied to computer usage as labels for these processes--information input, storage, coding, manipulating or operating on the information, decoding, retrieval, and output. We will use the more traditional psychological terminology--sensing, discriminating, cognizing, hypothesizing, abstracting, generalizing, remembering, and responding.

In a prior set of experiments supported by U.S.O.E., Klausmeier, Harris, and Wiersma (1964) dealt with hypothesizing behavior in a limited manner while studying selection strategies of the type proposed by Bruner, Goodnow, and Austin (1956). In those experiments it was clear that formulating and testing hypotheses were central processes in global selection strategies. The present experiments were conducted to secure a more complete understanding of hypothesizing behavior by studying the effect of preliminary training and experimental experience on the hypotheses held by subject.

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[1]The present report is based on data collected by J. Kent Davis and Daniel Lynch (experiments 4 and 5) and on a Ph.D. thesis conducted by Daniel Lynch (experiment 6), during the academic years 1965-66 and 1967-68, under the supervision of Herbert J. Klausmeier. The report was written by Dorothy Frayer and Herbert J. Klausmeier.

Experiment 4: Hypothesizing Behavior and Learning Set

Purpose

Levine (1963) reported an experimental method and a concept formation model specifically designed to clarify the nature of hypothesizing as a mediational process. The method was devised to enable the experimenter to unambiguously infer the subject's hypothesis on a given problem by his sequence of responses in the absence of feedback. Stimuli employed varied in dimensions, e.g., color, form, position, and size, and each dimension varied in value, e.g., large-small, white-black, etc. The sequence of stimuli for a problem was chosen in such a way that each level of each dimension appeared an equal number of times with every value of every other dimension. A problem constructed in this manner was described as internally orthogonal. Such a sequence is shown in Figure 4.1. In the absence of feedback, each different hypothesis resulted in a unique response pattern on an internally orthogonal problem. Thus, a problem with no feedback (nonoutcome problem) was used as a probe to detect the hypothesis held by a subject as a function of outcomes on previous problems.

Levine based his 1963 experiments on several assumptions about hypothesizing behavior in concept learning. These assumptions which were verified and extended in a later experiment (Levine, 1966), were as follows:

1. At the outset of a problem a subject selects one hypothesis from the total finite set which experimenter indicates to him. If no outcome is given following subject's choice he keeps the same hypothesis on succeeding trials.

2. When a subject makes a first-trial prediction that is followed by "right," he makes the same prediction on subsequent trials.

3. When a subject makes a first-trial prediction that is followed by "wrong," he rejects this prediction and resamples from the total set of possible hypotheses. The probability is high that the new value chosen as a hypothesis will be one of the four values which was not incorporated in the stimulus labeled "wrong."

In addition to these general conclusions, Levine (1963) also reported the following more specific phenomena, which may be seen in Figure 4.2:

1. The position hypothesis rarely occurred.

2. A small increase in the strength of apparently extinguished hypotheses occurred when the learning set changed.

3. More proficiency was achieved on the first learning set, "color," than on the second learning set, "form."

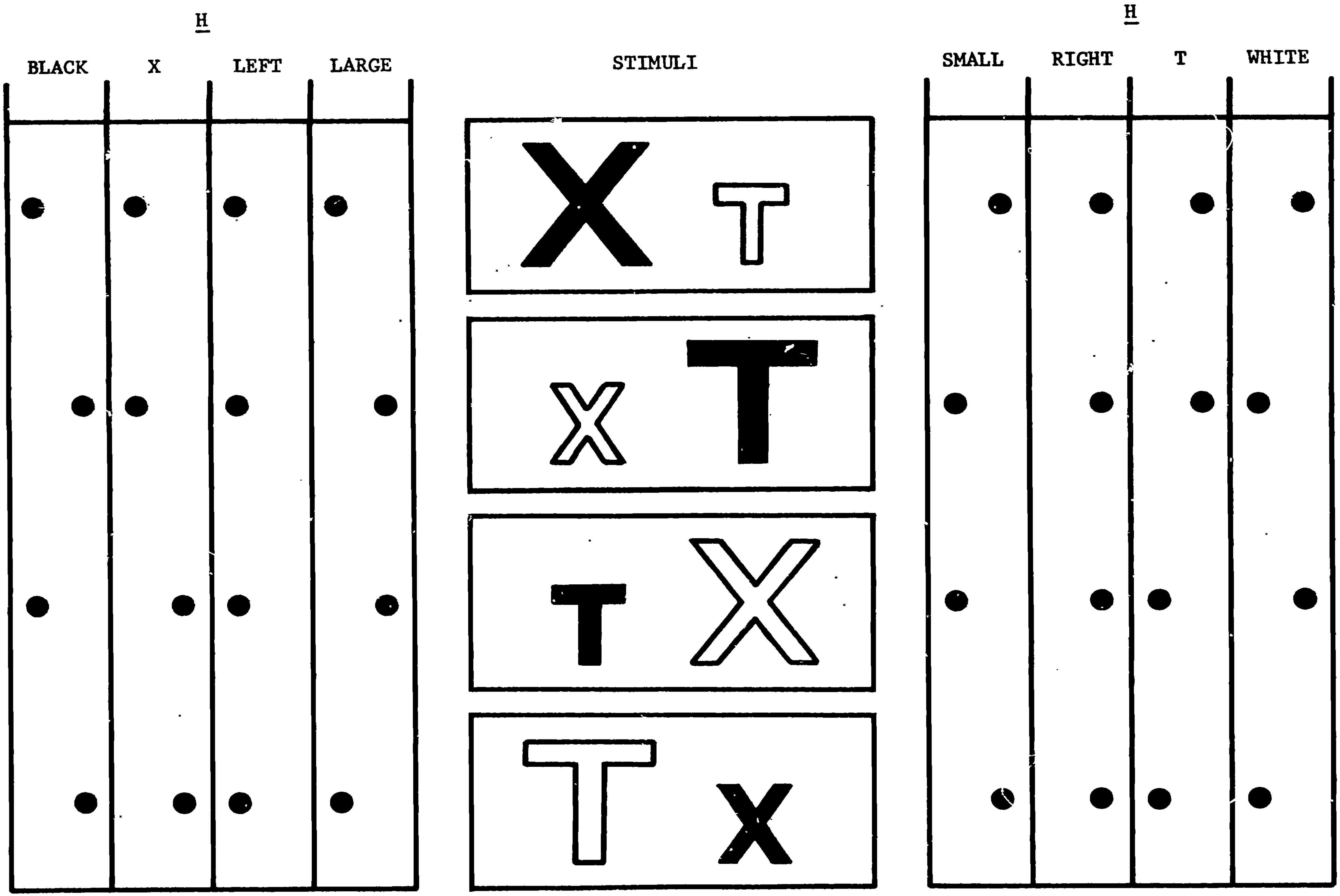


Figure 4.1. Eight patterns of choices corresponding to each of the eight Hs when the four stimulus pairs are presented consecutively without outcomes.

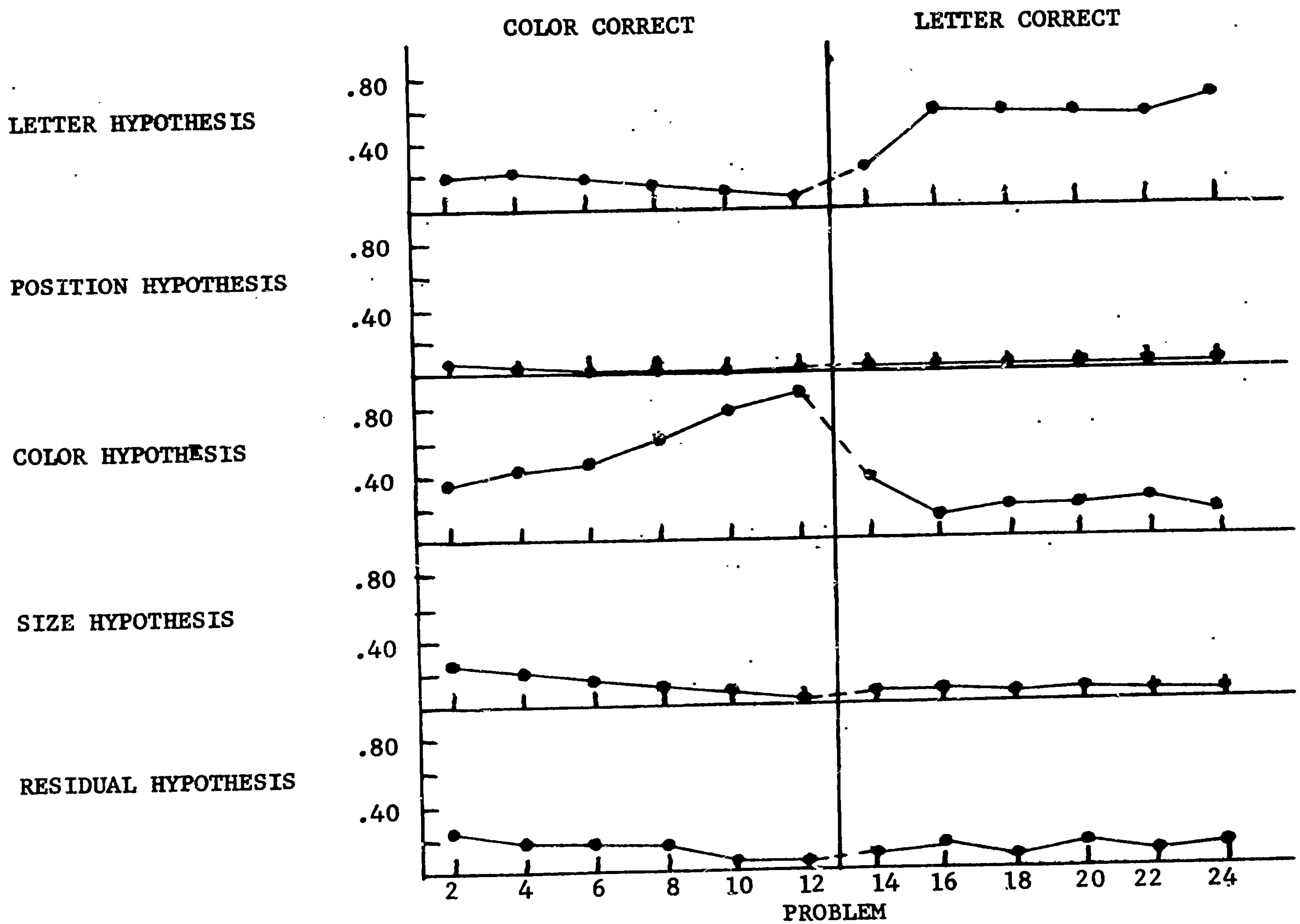


Figure 4.2. The probability of occurrence of the various hypotheses, after Levine, 1963.

The purpose of the present experiment was to ascertain whether the hypothesizing phenomena observed by Levine were replicable. In addition, two different orders of learning sets were studied to determine whether the greater proficiency of the color prediction which had been observed by Levine was due to an established preference for color, or to its serial position--first of the two.

Subjects

Subjects in experiment 4 were 196 University of Wisconsin students. All subjects were paid for participating.

Experimental Materials

Stimulus materials were geometric figures varying on four bi-valued dimensions, form, position, color, and size. For each problem, pairs of consonants of the alphabet were randomly selected. These consonants comprised the two values of the form dimension. The values for the color dimension were determined by randomly selecting two of seven colors (purple, blue, green, yellow, brown, red, and white). The figures were positioned on the right or on the left, and were large or small. Within a given four-trial problem each level of each dimension occurred equally often with each level of every other dimension. Thus, the criterion for internal orthogonality was met. Twenty-four problems were constructed according to the procedures outlined above, with the following restrictions: (a) no letters or colors were repeated in any two consecutive problems, (b) no consonant appeared more than three times, (c) no color appeared more than seven times. Table 4.1 gives the exact specification of the stimulus materials.

Experimental Design

The subjects were divided into four groups. Each group received a preliminary demonstration problem followed by the 24 problems of the experiment. The preliminary problem was comprised of the same four dimensions as the experimental materials, but was 14 trials in length. The 24 four-trial problems of the experiment consisted of 18 outcome problems and six nonoutcome problems. For groups 1A (N=49) and 1B (N=47) one of the two colors always served as the basis for correct responding to outcome problems in problems 1-12; on problems 13-24 one of the two letters always served as the basis for correct responding. For groups 2A (N=50) and 2B (N=50), a letter was the correct response for problems 1-12, and a color for problems 13-24. Groups 1A and 2A received the nonoutcome condition on problems 2, 6, 10, 14, 18, and 22, while groups 1B and 2B received the nonoutcome condition on problems 4, 8, 12, 16, 20, and 24. Table 4.2 illustrates the design for experiment 4.

Table 4.1

Stimulus Material Specifications

Pretraining Problem

	Color				Letter				Size			
	Red		Green		A		E		Large		Small	
	L	R	L	R	L	R	L	R	L	R	L	R
1.	X*			X	X			X		X	X	
2.	X			X		X	X		X			X
3.		X	X		X			X	X			X
4.		X	X			X	X			X	X	
5.	X			X		X	X			X	X	
6.		X	X		X			X		X	X	
7.		X	X			X	X		X			X
8.	X			X	X			X	X			X
9.		X	X			X	X		X			X
10.		X	X		X			X		X	X	
11.	X			X	X			X	X			X
12.	X			X		X	X			X	X	
13.	X			X		X	X			X	X	
14.		X	X		X			X		X	X	

PROBLEM 1

	Color				Letter				Size			
	Yellow		Brown		W		F		Large		Small	
	L	R	L	R	L	R	L	R	L	R	L	R
1.	X			X	X			X		X	X	
2.		X	X			X	X			X	X	
3.	X			X		X	X		X			X
4.		X	X		X			X	X			X

PROBLEM 2

	Color				Letter				Size			
	Red		Green		B		C		Large		Small	
	L	R	L	R	L	R	L	R	L	R	L	R
1.	X			X	X			X	X			X
2.		X	X		X			X		X	X	
3.		X	X			X	X		X			X
4.	X			X		X	X			X	X	

*The first "X" for slide 1. of the pretraining problem means that the lefthand letter was red. The next indicates that the righthand letter was green. The next indicates the lefthand letter was an A, etc.

PROBLEM 3

	Color				Letter				Size			
	Brown		Purple		V		R		Large		Small	
	L	R	L	R	L	R	L	R	L	R	L	R
1.	X			X	X			X	X			X
2.	X			X		X	X			X	X	
3.		X	X		X			X		X	X	
4.		X	X			X	X		X			X

PROBLEM 4

	Color				Letter				Size			
	Green		White		Z		Q		Large		Small	
	L	R	L	R	L	R	L	R	L	R	L	R
1.	X			X	X			X	X			X
2.		X	X			X	X		X			X
3.		X	X		X			X		X	X	
4.	X			X		X	X			X	X	

PROBLEM 5

	Color				Letter				Size			
	Brown		Red		R		J		Large		Small	
	L	R	L	R	L	R	L	R	L	R	L	R
1.	X			X	X			X		X	X	
2.		X	X		X			X	X			X
3.		X	X			X	X			X	X	
4.	X			X		X	X		X			X

PROBLEM 6

	Color				Letter				Size			
	Blue		White		Y		C		Large		Small	
	L	R	L	R	L	R	L	R	L	R	L	R
1.	X			X	X			X		X	X	
2.		X	X			X	X			X	X	
3.	X			X		X	X		X			X
4.		X	X		X			X	X			X

PROBLEM 7

	Color				Letter				Size			
	Red		Green		G		T		Large		Small	
	L	R	L	R	L	R	L	R	L	R	L	R
1.	X			X	X			X		X	X	
2.		X	X		X			X	X			X
3.	X			X		X	X		X			X
4.		X	X			X	X			X	X	

PROBLEM 8

	Color				Letter				Size			
	Yellow		Brown		Y		H		Large		Small	
	L	R	L	R	L	R	L	R	L	R	L	R
1.	X			X	X			X		X	X	
2.		X	X		X			X	X			X
3.		X	X			X	X			X	X	
4.	X			X		X	X		X			X

PROBLEM 9

	Color				Letter				Size			
	Purple		Green		V		W		Large		Small	
	L	R	L	R	L	R	L	R	L	R	L	R
1.	X			X	X			X	X			X
2.	X			X		X	X			X	X	
3.		X	X			X	X		X			X
4.		X	X		X			X		X	X	

PROBLEM 10

	Color				Letter				Size			
	Red		White		K		D		Large		Small	
	L	R	L	R	L	R	L	R	L	R	L	R
1.	X			X	X			X	X			X
2.	X			X		X	X			X	X	
3.		X	X		X			X		X	X	
4.		X	X			X	X		X			X

PROBLEM 11

	Color				Letter				Size			
	Yellow		Blue		G		F		Large		Small	
	L	R	L	R	L	R	L	R	L	R	L	R
1.	X			X	X			X	X			X
2.		X	X			X	X		X			X
3.		X	X		X			X		X	X	
4.	X			X		X	X			X	X	

PROBLEM 12

	Color				Letter				Size			
	White		Brown		R		L		Large		Small	
	L	R	L	R	L	R	L	R	L	R	L	R
1.	X			X	X			X		X	X	
2.		X	X			X	X			X	X	
3.	X			X		X	X		X			X
4.		X	X		X			X	X			X

PROBLEM 13

	Color				Letter				Size			
	Purple		Blue		M		J		Large		Small	
	L	R	L	R	L	R	L	R	L	R	L	R
1.	X			X	X			X	X			X
2.	X			X		X	X			X	X	
3.		X	X		X			X		X	X	
4.		X	X			X	X		X			X

PROBLEM 14

	Color				Letter				Size			
	Red		Yellow		G		N		Large		Small	
	L	R	L	R	L	R	L	R	L	R	L	R
1.	X			X	X			X	X			X
2.		X	X		X			X		X	X	
3.		X	X			X	X		X			X
4.	X			X		X	X			X	X	

PROBLEM 15

	Color				Letter				Size			
	Brown		Blue		T		X		Large		Small	
	L	R	L	R	L	R	L	R	L	R	L	R
1.	X			X	X			X		X	X	
2.	X			X		X	X		X			X
3.		X	X		X			X	X			X
4.		X	X			X	X			X	X	

PROBLEM 16

	Color				Letter				Size			
	Green		Purple		B		V		Large		Small	
	L	R	L	R	L	R	L	R	L	R	L	R
1.	X			X	X			X	X			X
2.		X	X			X	X		X			X
3.		X	X		X			X		X	X	
4.	X			X		X	X			X	X	

PROBLEM 17

	Color				Letter				Size			
	Brown		Yellow		M		Y		Large		Small	
	L	R	L	R	L	R	L	R	L	R	L	R
1.	X			X	X			X		X	X	
2.		X	X			X	X			X	X	
3.	X			X		X	X		X			X
4.		X	X		X			X	X			X

PROBLEM 18

	Color				Letter				Size			
	Purple		Blue		H		B		Large		Small	
	L	R	L	R	L	R	L	R	L	R	L	R
1.	X			X	X			X	X			X
2.		X	X		X			X		X	X	
3.	X			X		X	X			X	X	
4.		X	X			X	X		X			X

PROBLEM 19

	Color				Letter				Size			
	White		Yellow		F		K		Large		Small	
	L	R	L	R	L	R	L	R	L	R	L	R
1.		X	X		X			X	X			X
2.	X			X	X			X		X	X	
3.		X	X			X	X			X	X	
4.	X			X		X	X		X			X

PROBLEM 20

	Color				Letter				Size			
	Red		Purple		C		Q		Large		Small	
	L	R	L	R	L	R	L	R	L	R	L	R
1.	X			X	X			X	X			X
2.	X			X		X	X			X	X	
3.		X	X			X	X		X			X
4.		X	X		X			X		X	X	

PROBLEM 21

	Color				Letter				Size			
	White		Yellow		H		N		Large		Small	
	L	R	L	R	L	R	L	R	L	R	L	R
1.		X	X		X			X		X	X	
2.	X			X	X			X	X			X
3.		X	X			X	X		X			X
4.	X			X		X	X			X	X	

PROBLEM 22

	Color				Letter				Size			
	Green		Blue		P		J		Large		Small	
	L	R	L	R	L	R	L	R	L	R	L	R
1.	X			X	X			X	X			X
2.	X			X		X	X			X	X	
3.		X	X			X	X		X			X
4.		X	X		X			X		X	X	

PROBLEM 23

	Color				Letter				Size			
	White		Purple		Z		X		Large		Small	
	L	R	L	R	L	R	L	R	L	R	L	R
1.	X			X	X			X		X	X	
2.	X			X		X	X		X			X
3.		X	X			X	X			X	X	
4.		X	X		X			X	X			X

PROBLEM 24

	Color				Letter				Size			
	Red		Blue		S		T		Large		Small	
	L	R	L	R	L	R	L	R	L	R	L	R
1.	X			X	X			X		X	X	
2.		X	X			X	X			X	X	
3.		X	X		X			X	X			X
4.	X			X		X	X		X			X

Table 4.2

Experimental Design for Experiment 4

Pretraining	Problem	2	4	6	8	10	12	14	16	18	20	22	24
		Color Relevant						Letter Relevant					
	Group 1A	*		*		*		*		*		*	
	Group 1B		*		*		*		*		*		*
Size		Letter Relevant						Color Relevant					
	Group 2A	*		*		*		*		*		*	
	Group 2B		*		*		*		*		*		*

*Problems on which the nonoutcome procedure will be followed.

Experimental Procedure

The subjects participated in the experiment in groups. The first pair of stimuli from the preliminary problem was projected on the screen while the initial instructions were read. The preliminary problem required responding to 14 pairs of stimuli. After each of the 14 trials, the experimenter gave the group the correct basis for responding. The experiment proper followed immediately.

For the 18 four-trial outcome problems, the experimenter pointed to the correct stimulus at the conclusion of each trial. Subjects were allowed 10 seconds to respond on an IBM answer sheet, and then the experimenter pointed to the correct stimulus. Total exposure time was 12 seconds for each trial.

The tape recorded instructions were as follows:

> In this experiment you will be presented with several easy problems. Each problem consists of a series of cards like this one. (The first slide was on the screen.) During this experiment your task will be to decide which of the two stimuli is the correct stimulus. Indicate in the first answer space on your IBM answer sheet the stimulus you think is correct. Do this by either filling the blank column marked "T" for the left-hand stimulus or by filling the blank column marked "F" for the right-hand stimulus. You will be shown which stimulus was correct after you have indicated your answer. There is going to be a series of stimuli like this first slide. You are to follow the same procedure on them as you are following on this pair of stimuli. Please mark your first answer.
>
> (Five second pause.)
>
> By now you should have marked your choice on your answer sheet. Throughout this experiment do not change your answer when the correct answer is given. The correct stimulus on this slide is the stimulus on the right. (Experimenter pointed to the correct stimulus.) You should have filled in the "F" column in the first answer space if you were correct. Please answer as soon as possible after each stimulus is presented. For each slide, I will point to the correct stimulus after you have filled in your answer. (The remaining 13 example slides were now presented.)
>
> The larger letter was the correct stimulus for each of these first 14 slides. These slides were a demonstration problem. The stimuli in this problem varied on the four dimensions of size, position, color, and shape. A given stimulus was either large or small, either on the right or on the left, either red or green, and either an 'A' or an 'E'.

In each of the remaining problems, one of these cues will always give the correct answer. For each slide I want you to tell me which of these two you think is correct and I'll tell you whether or not you are correct. In this way you can learn the basis for my designating which stimulus is correct. You can figure out whether it is because of the color, the letter, the size, or the position. The object for you is to figure this out as fast as possible so that you can choose correctly as often possible.

Before all nonoutcome problems the following instructions were given:

> The next problem will be a test of how much you have learned thus far. During the next problem I will not point to the correct stimulus on each slide presentation. Because this is a test, you are to continue to try to get 100 percent correct.

Results

The dependent variable in this study was the percent of subjects manifesting the response pattern corresponding to each hypothesis on each nonoutcome problem. The particular hypothesis a subject used to guide his responding on a nonoutcome problem was determined by classifying his response pattern on a given problem in terms of five possible types of hypotheses--position, color, letter, size, and residual. The subject was classified as using a position hypothesis if he placed his responses all in the left or all in the right column of his IBM sheet for a given problem. The subject was classified as using a color, letter, or size hypothesis if his response pattern matched the respective pattern listed for that hypothesis in Table 4.1. The subject was classified as using a residual hypothesis if three of his responses to a problem were in one column of his answer sheet and one response was in the other column.

The percent of subjects manifesting each hypothesis on each nonoutcome problem of this experiment are presented in Table 4.3 and Figure 4.3. Several facts should be recalled in examining Figure 4.3. All data were obtained from nonoutcome problems and the data points represent two different groups of subjects alternating on nonoutcome problems. A change of approximately two percent in a graphed line represents one person changing his hypothesis. Thus, many observable differences are numerically quite small.

The primary result of this experiment which may be noted in Figure 4.3 was that when a particular dimension was relevant over a series of outcome problems, the proportion of subjects hypothesizing that dimension on nonoutcome problems increased. This held true for both color and letter learning sets and occurred for the first learning set (problems 1-12) and for the second learning set (problems 13-24).

Table 4.3

Percent of Subjects Exhibiting Each Hypothesis on Nonoutcome

Problems in Experiment 4

	GROUP 1A							GROUP 1B					
PROBLEM	2	6	10	14	18	22	PROBLEM	4	8	12	16	20	24
Letter	12	12	16	41	61	59	Letter	28	2	8	72	53	68
Position	2	0	0	0	4	2	Position	0	0	0	0	4	4
Color	29	67	63	29	18	6	Color	53	89	87	13	11	17
Size	35	6	4	18	4	14	Size	8	6	2	6	11	6
Residual	22	14	16	12	12	18	Residual	11	2	2	8	21	4

	GROUP 2A							GROUP 2B					
PROBLEM	2	6	10	14	18	22	PROBLEM	4	8	12	16	20	24
Letter	10	58	74	32	6	18	Letter	42	54	70	4	6	6
Position	2	2	0	12	4	2	Position	2	0	0	0	0	0
Color	22	24	10	24	74	58	Color	24	28	16	70	62	76
Size	52	8	4	28	6	10	Size	10	8	8	8	12	2
Residual	14	8	12	4	10	12	Residual	22	10	6	18	20	16

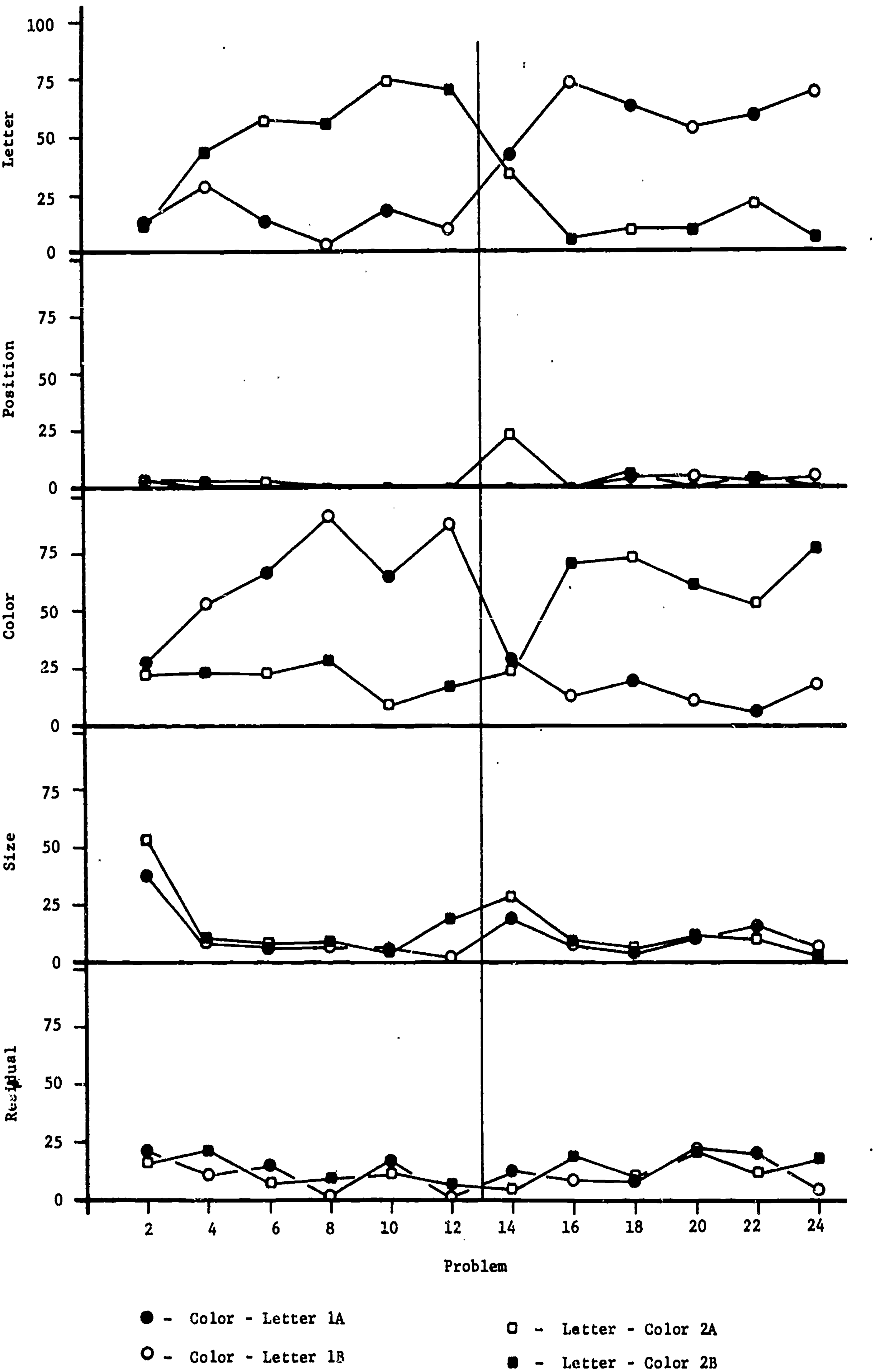


Figure 4.3 Percent of $\underline{S}$s exhibiting each hypothesis on nonoutcome problems in Experiment 4.

Comparison of Figures 4.2 and 4.3 reveals that Levine's results have also been replicated in the following respects:

1. The position hypothesis rarely occurred.

2. A small increase in the strength of apparently extinguished hypotheses occurred when the learning set changed.

3. For groups 1A and 1B, which were comparable to the two groups used by Levine, more proficiency was achieved on the first learning set, "color" than on the second learning set, "letter."

This last result may be clarified by comparison with groups 2A and 2B. Levine (1963) pointed out that this phenomenon might indicate that color was more salient than letter. In Levine's procedures, however, color learning set preceded letter learning set, and therefore, fatigue and other sequence effects may have depressed performance on the letter set. In the present experiment, color-letter learning set sequence was compared with letter-color sequence in order to isolate the effect of salience. Conclusions must be tentative since differences existed between A and B groups, indicating measurement was not totally reliable. It appears, however, that subjects gained more proficiency on their first learning set than on their second. Although the percent of color hypotheses offered when color was relevant was slightly higher than the percent of letter hypotheses offered when letter was relevant, the difference was not large enough to provide solid evidence for salience of the color dimension.

One final fact should be noted concerning the results of experiment 4. The percent of subjects offering each hypothesis differed markedly even on the first nonoutcome problem, problem 2. Several factors may account for this. Subjects may have brought a response set into the experimental situation. Phrasing of the instructions may have drawn attention to a specific dimension. Also, experience on the preliminary problem and the first outcome problem may have affected the probability of occurrence of each hypothesis.

Size was the most frequently offered hypothesis on problem 2 for both groups 1A and 2A. Color, letter, and position hypotheses followed, in that order. The fact that color was offered more frequently than letter as a hypothesis on problem 2 in group 2A where letter was relevant for problem 1 indicates that the effect of this single outcome problem was minimal. The preliminary problem, however, may have had a significant effect on initial hypothesizing behavior. The dimension, size, which was relevant for the preliminary problem, was the dimension most often chosen as a hypothesis on the first nonoutcome problem.

Discussion

The formulation and testing of hypotheses are crucial processes in concept attainment. Bruner, Goodnow, and Austin (1956) and Klausmeier, Harris, and Wiersma (1964) studied the sequence of hypothesis testing as a function of such variables as stimulus complexity, ordering of stimulus display, and consequences of failure to attain the concept in a minimal number of steps. The sequence of hypothesis testing was described by such general characteristics as the number of dimensions varied from the focus card, number of hypotheses eliminated with each card choice, number of redundant card choices, correctness of first hypothesis, and total number of dimensions tested. This characterization of hypothesizing sequence was global but reliable, and could be related to situational variables. No attempt was made in these experiments to ascertain the exact hypothesis held on a particular trial or problem as a result of prior experience. Bruner et al., however, noted that subjects brought into the experimental situation a "predilection" to select certain dimensions for testing.

In the present experiments, the particular dimension hypothesized was ascertained at several points over a series of problems. It was evident that subject's past experience strongly influenced the hypothesis which he entertained on a given problem. The outcome of all preceding problems affected subject's choice of hypothesis, with the greatest effect due to the immediately preceding problems. There was also evidence that subject's initial hypotheses were affected by experiences prior to the experiment, resulting in a response set or salience of a particular dimension. Thus, in the design and interpretation of concept learning experiments, the effects of problem sequence, and specific dimensions should be considered.

These experiments may also be related to Levine's generalizations concerning hypothesizing behavior. Levine's conclusion that subject retains his hypothesis over the trials of a nonoutcome problem was substantiated by the data of the present experiments. There were 16 possible response patterns for the problems employed. Eight of these response patterns corresponded to the hypotheses "letter," "position," "color," and "size" (see Figure 4.1). The other eight response patterns (3-1 patterns) were classified as residual hypotheses. If subject changed his hypothesis over the trials of a nonoutcome problem, a 3-1 pattern resulted. Evidence that this seldom occurred is found in the fact that over all nonoutcome problems in both experiments, only 12.8 percent of all patterns fell into this classification. This is actually an overestimate of the percent of changed hypotheses, since the residual category also included problems on which subject maintained a single hypothesis but erred in responding. Hypotheses were maintained on at least 87.2 percent of all nonoutcome problems.

Indirect confirmation was also obtained for Levine's conclusions that subject maintains his hypothesis when told he is correct, and changes his hypothesis when told he is incorrect. Levine's conclusions related to the conditions under which hypotheses would be altered over the trials of an outcome problem. It seems reasonable to assume that subject's hypothesis on a nonoutcome problem would be related to the previous outcome problem, particularly since both outcome and nonoutcome problems were comprised of the same dimensions. If this assumption is tenable, then the regular increase in hypotheses congruent with the relevant learning set and decrease in the other hypotheses would reflect retention of correct hypotheses and rejection of incorrect hypotheses.

Experiment 5: Hypothesizing Behavior, Preexperimental Training, and Learning Set

Purpose

In order to ascertain the effect of preliminary training on hypothesizing behavior, performance on a series of learning set problems was compared for groups having had different dimensions relevant on a pretraining problem.

Subjects

Subjects in experiment 5 were 204 University of Wisconsin students. None of these subjects had taken part in experiment 4, and all were paid for participating.

Experimental Material and Procedure

Materials and procedure were identical to experiment 4 except that in the preliminary problem a color or letter was relevant instead of size.

Experimental Design

Four groups of subjects solved 24 four-trial problems, with color the correct basis for responding on problems 1-12, letter on problems 13-24. Groups 3A (N=50) and 3B (N=50) had color as the relevant dimension for the pretraining problem. Groups 4A (N=52) and 4B (N=52) had letter as the relevant dimension during pretraining. Groups 3A and 4A received the nonoutcome condition on problems 2, 6, 10, 14, 18, and 22 and groups 3B and 4B received the nonoutcome condition on problems 4, 8, 12, 16, 20, and 24. Table 5.1 presents the design for experiment 5.

Results

Percent of subjects exhibiting each hypothesis on nonoutcome problems in experiment 5 are presented in Table 5.2 and Figure 5.1.

Table 5.1

Experimental Design for Experiment 5

Pretraining		Color Relevant						Letter Relevant					
	Problem	2	4	6	8	10	12	14	16	18	20	22	24
Color	Group 3A	*		*		*		*		*		*	
	Group 3B		*		*		*		*		*		*
Letter	Group 4A	*		*		*		*		*		*	
	Group 4B		*		*		*		*		*		*

*Problems on which the nonoutcome procedure will be followed.

Table 5.2

Percent of Subjects Exhibiting Each Hypothesis on Nonoutcome

Problems in Experiment 5

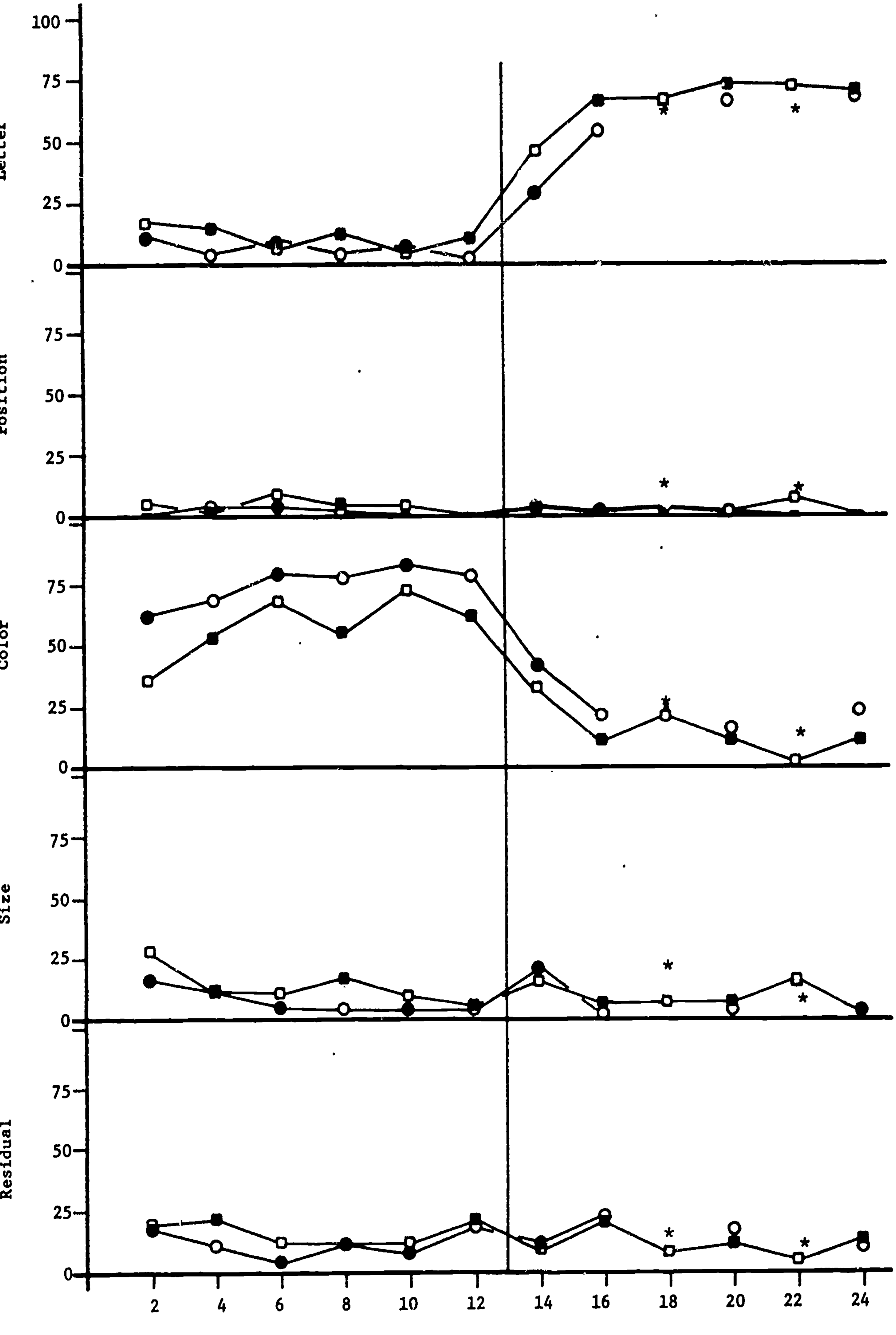
GROUP 3A						
PROBLEM	2	6	10	14	18	22
Letter	8	8	6	26	*	*
Position	0	4	0	2	*	*
Color	62	80	82	40	*	*
Size	14	4	4	20	*	*
Residual	16	4	8	12	*	*

GROUP 3B						
PROBLEM	4	8	12	16	20	24
Letter	4	4	2	58	64	66
Position	4	2	0	0	2	0
Color	68	78	78	18	14	20
Size	12	4	4	2	4	4
Residual	12	12	16	22	16	10

GROUP 4A						
PROBLEM	2	6	10	14	18	22
Letter	15	6	4	46	65	73
Position	4	6	4	2	2	6
Color	35	67	71	31	19	2
Size	27	10	10	14	6	15
Residual	19	12	12	8	8	4

GROUP 4B						
PROBLEM	4	8	12	16	20	24
Letter	14	12	10	64	73	71
Position	2	4	0	2	0	0
Color	52	58	62	10	10	10
Size	12	15	6	6	6	4
Residual	21	12	23	19	12	15

*Data omitted due to procedural error on problem 17 for Group 3A.



● - Color Pretraining 3A

○ - Color Pretraining 3B

□ - Letter Pretraining 4A

■ - Letter Pretraining 4B

* Data points for problems 18 & 22 omitted due to procedural error on problem 17 for group 3A.

Figure 5.1 Percent of Ss exhibiting each hypothesis on nonoutcome problems in Experiment 5.

Data on problems 18 and 22 for group 3A are omitted, since an experimenter error occurred in problem 17. For both groups 3A and 4A, color was the most frequently offered hypothesis on problem 2, followed by size, letter, and position. Color was more frequently hypothesized than letter by group 4A, even though it had received letter pretraining. Relatively more letter hypotheses were offered on problem 2 by group 4A than by group 3A, however, indicating some effect due to pretraining.

The fact that color was hypothesized more frequently than letter by group 4A on the first nonoutcome problem suggests the color had a salience effect which outweighed the effect of letter pretraining.

The effect of pretraining appears to be relatively small and short-term. The percent of subjects exhibiting each hypothesis is generally quite similar for the two pretraining groups.

Discussion

The regular form of the learning-set curves in experiment 5 indicated that the subjects were offering hypotheses in a systematic, predictable manner, apparently searching for the attribute which was the basis for correct responding.

The effect of pretraining appeared to be minimal and of relatively short duration. It would be expected that the hypothesis which was correct on the pretraining problem might be offered as the initial hypothesis on the succeeding outcome problem. If the hypothesis proved incorrect for that problem, however, it would be rejected. On subsequent nonoutcome problems, the outcome of the immediately preceding problem would probably have a stronger effect on the hypothesis than the pretraining problem.

Further clarification of the effect of pretraining might be obtained by comparing groups having a preliminary problem with groups having no preliminary problem. A quantitative comparison of the duration of pretraining effects would also be desirable.

Experiment 6: Hypothesizing Behavior, Length of Problem Sequence, and Preexperimental Training

Purpose

In experiments 4 and 5 the effects of different relevant dimensions, learning-set sequences, and pretraining on hypothesizing behavior were studied on an exploratory level. Experiment 6 was designed to investigate these variables in a more rigorous and quantitative manner. The questions to be answered were: (1) Is hypothesizing behavior similar regardless of the particular dimension designated as the correct solution by experimenter? (2) How

long a sequence of problems having the same relevant dimension is necessary before a learning set develops? (3) How do the residual effects of a learning set vary as a function of number of interpolated problems? (4) What are the immediate and long-term effects of pretraining?

Subjects

Subjects were 160 University of Wisconsin educational psychology students. None of these subjects had taken part in experiments 4 or 5. Participation in the experiment fulfilled a course requirement.

Experimental Materials

The material used in the present study differed in two essential ways from those used in experiments 4 and 5. First, the present study used verbal rather than figural stimuli. Second, each dimension had four possible values; in the previous experiments the number of values per dimension differed.

The stimuli consisted of two sets of four words each, typed and reproduced in elite capital letters on 3 x 5 inch index cards. Figure 6.1 illustrates a typical stimulus card. Within a given word set, the top word was an adjective denoting size, next an adjective denoting color, next shape, and lastly position. The possible words within any set of four words were: HUGE, LARGE, SMALL, TINY, BLUE, GREEN, YELLOW, RED, ROUND, SQUARE, TRIANGULAR, OVAL, RIGHT, LEFT, TOP, BOTTOM. The two word sets for the first card of each problem were randomly chosen within the restrictions that the two word sets did not intersect and no word set appeared at the beginning of more than one problem. Within any given problem, the dimensional values varied in an internally orthogonal manner. With the exception of the pretraining problem, all problems consisted of four trials.

The stimulus cards were kept in a tray and were flipped forward by the subjects as they went through the experiment. Stacks of answer cards were used to inform the subjects whether the first or second word set was correct for each trial. Figure 6.1 illustrates a typical answer card.

A Cousino, Model #7341, continuous tape recorder was used to auditorily signal the beginning and end of a 10.5-second response interval, and a 3.5-second feedback interval.

Experimental Procedure

Subjects participated in the experiment in groups. When subject arrived, he sat at an individual table on which there were two ball point pens, a tray of stimulus cards on the left, a stack of answer cards on the right, a set of instructions, and a response booklet.

P 1

SMALL	LARGE
RED	YELLOW
TRIANGULAR	OVAL
RIGHT	BOTTOM

Stimulus Card

P 1 FIRST

Answer Card

Figure 6.1. Examples of Stimulus and Answer Cards.

The subjects in groups A and B read the following instructions silently while the experimenter read them aloud:

> You should have two pens, two stacks of cards, and a response booklet. Notice the top card on the left stack. It contains the words SMALL, RED, TRIANGULAR, and RIGHT in the first word set. It contains the words LARGE, YELLOW, OVAL, and BOTTOM in the second word set. Notice that the top word in each set on this practice card is a word denoting size, the next word denotes color, the next denotes shape, and the last denotes position. During this experiment, your task will always be to decide which of the two word sets on a given card is correct. You are to decide which word set is correct on the basis of one of the four words in each word set. You will indicate which word set you think is correct by writing "first" on your answer sheet if you think the first or lefthand word set is correct and by writing "second" on your answer sheet if you think the second or righthand word set is correct. On the first extra line on the front of your response booklet write which word set you guess is correct. (Experimenter pointed out that this was a practice card and observed that subjects responded properly.) Notice that this first practice card is numbered P1. Now remove the other card numbered P1 from the other card stack, turn it face up, and read it. (Experimenter observed that subjects responded properly.)
>
> You will now go through a run of 15 practice cards to familiarize yourself with the procedures and pacing of the present experiment. At the beginning of each trial you will hear a "beep." At this signal you will read the stimulus card and write on your answer sheet whichever word set you guess is correct on your stimulus card. About ten seconds after the first beep will be a second beep. You are to then place the word set card face down and then turn over the top answer card and read what the correct answer is on that trial. About three seconds after the beep telling you to read the answer card will be the beep telling you to begin the next trial. You will now run through practice cards 2 through 16 responding either "first" or "second" for each card on the remaining space on the front of your response booklet. (Subjects were at this point given a demonstration of the machine's beeping and of the card turning procedures.) Read the stimulus card, write an answer, and turn the stimulus card face down during the long interval; turn face up and read the answer card during the short interval. Are there any questions?

After any questions were answered, experimenter stated "Remember, these practice cards are merely to establish the rhythm or pacing of the experiment." Subjects then went through the practice run.

During the practice run, all answer cards contained:

> This is a practice answer card. On an actual experimental trial this card would have contained either the word FIRST or SECOND to signify which word set on the stimulus card was correct.

This procedure was employed to provide subjects in groups A and B with stimulus familiarization without providing them with a pretraining problem. During the practice run experimenter observed whether or not subjects responded in the appropriate fashion and corrected them if they did not.

After the practice run, subjects were told:

> You have now completed the practice run. During the experiment you will proceed just as you have done so far except that some of your answer cards will be blank. These will be test trials. Remember to follow the machine pacing. Read the stimulus card and write your answer during the long interval; then read the answer card during the short interval. Are there any questions?

Subjects were now run through the 64 problems.

The instructions and procedures used for group C were essentially the same at the beginning of the experiment as those for groups A and B. The answer cards for group C, however, contained answers instead of a statement that this was a practice answer card. Subjects in group C were informed after the practice problem that either the word "red" or the word "triangular" (depending on the treatment group) had determined the correct word set during the practice problem.

The same set of stimulus cards was used for all treatments.

The decks of answer cards used varied according to treatment groups.

Experimental Design

The design for this experiment is presented in Table 6.1. Each subject in groups A and B received a total of 64 four-trial problems (eight blocks of eight problems each) without interruption; each subject in group C received 32 four-trial problems. Each letter in Table 6.1 represents a block of eight four-trial problems and specifies the relevant dimension for the block of problems. Within each block of eight problems, six were outcome

Table 6.1

Experimental Design for Experiment 6

		Pretraining	Problems 1-8	9-16	17-24	25-32	33-40	41-48	49-56	57-64
Group A	A1.	none	a	a	a	a	b	c	d	_a_
	A2.		b	b	b	b	c	_b_	a	d
	A3.		c	c	c	c	a	d	_c_	b
	A4.		d	d	d	d	_d_	a	b	c
Group B	B1.	none	b	c	d	a	b	c	d	a
	B2.		c	b	a	d	c	b	a	d
	B3.		a	d	c	b	a	d	c	b
	B4.		d	a	b	c	d	a	b	c
Group C	C1.	b	b	c	a	d				
	C2.	b	d	a	c	b				
	C3.	d	b	c	a	d				
	C4.	d	d	a	c	b				

a = size relevant
b = color relevant
c = position relevant
d = shape relevant

Note: At problems 57-64 for subgroup A1, the letter "_a_" is underlined to emphasize that that set of problems provides an estimate of the residual effect of the first 32 problems in which size was always relevant. Similar generalizations are true of subgroups A2, A3, and A4.

problems (subjects were informed of the correct answer after each trial) and two were nonoutcome problems (subjects were not informed of the correct answer after each trial); within each block of problems, half the subjects received nonoutcome problems at problems 2 and 6, the other half at problems 4 and 8.

The first part of the experiment compared the effects of two types of problem sequences. Each subject in group A had the same dimension relevant over the first 32 problems, while each subject in group B went through four sequential learning-set series of eight problems each. Data for the subgroups in group A permitted comparison of the hypothesis learning curves for each dimension. Data for problems 33-64 allowed evaluation of the residual effects of the two types of problem sequences encountered by groups A and B on problems 1-32.

The second part of the experiment dealt with the effect of pretraining on hypothesizing behavior. The choice of relevant dimensions for the pretraining problems presented to group C were determined from the results obtained from group A on problems 1-32. No significant differences attributable to difference in relevant dimensions were found among subgroups A_1-A_4 on problems 1-32. Although not significantly different, the color dimension produced the highest and the shape dimension produced the lowest learning-set curve for subgroups A_1-A_4 on problems 1-32. Because these two learning-set curves were likely to represent the range of variation in learning sets attributable to dimension effects, they were chosen as the pretraining dimensions for subgroups C_1-C_4. The problem sequences following pretraining were designed to clarify residual effects resulting from pretraining.

Results

The dependent variable of the present study was the type of response pattern exhibited on nonoutcome problems. A response pattern on a nonoutcome problem was classified in terms of three types of hypotheses: (1) relevant: the dimension hypothesized had been relevant for the immediately preceding outcome problem, (2) irrelevant: the dimension hypothesized had been irrelevant for the immediately preceding outcome problem, (3) residual: the response pattern did not fit any of the dimensions of the stimulus set. These three mutually exclusive and exhaustive categories were treated as three dichotomous dependent variables. A score of one was assigned when a response pattern belonged to the category; a score of zero when the pattern did not belong. Cochran (1950) has shown that the $\underline{F}$ statistic computed as if the dependent variable were normally distributed rather than dichotomous yields probability levels relatively close to true probability levels but the statistic will tend to be somewhat conservatively biased (i.e., it will tend to show statistically significant results somewhat less often than they truly occur).

The first analysis of this experiment was a 2 x 2 x 8 repeated measures ANOVA of the data of group A on the first 32 problems. There were two levels of nonoutcome-problem set (problems 2, 6, 10, etc., versus problems 4, 8, 12, etc.), four levels of the factor of dimension relevant on outcome-problems, and eight levels of nonoutcome-problem sequence position (first, second, etc. of the eight nonoutcome problems). The main effect of nonoutcome-problem sequence position was significant ($F = 3.48$, $df = 7/168$, $p < .01$). Its interaction involving nonoutcome-problem set was also significant ($F = 2.81$, $df = 7/168$, $p < .05$).

The problem sequence position main effect demonstrates learning. The interaction may reflect the fact that subjects receiving nonoutcome problems 2, 6, 10, etc. had a different training history starting with problem 2 than subjects receiving nonoutcome problems 4, 8, 12, etc.

The second analysis of this study was a 2 x 2 x 4 ANOVA of the data in the cells d, b, c, and a (underlined in Table 6.1) of group A, problems 33-64. This analysis was done to trace any residual effects on a particular relevant hypothesis resulting from interspersing 0, 8, 16, or 24 problems in which that dimension was irrelevant. The sequence position of each set of eight problems (d, b, c, and a) was confounded with the particular relevant dimension. Since the relevant dimension factor did not significantly affect performance in the first analysis ($F < 1$), it was considered legitimate to leave this effect confounded in this analysis. The independent variables were nonoutcome-problem set (2 levels), nonoutcome-problem sequence position (first or second problem) and learning-set sequence position (the 4 sequence positions of cells d, b, c, and a). The only significant effect was that of nonoutcome-problem sequence position ($F = 5.65$, $df = 1/24$, $p < .05$). On the dependent variable of relevant hypotheses, the mean for the first nonoutcome problem was .41 and for the second .66. Analysis of the other cells of group A on problems 33-64 did not show a similar improvement.

Additional analyses were performed on the data of groups A and B comparing group A with group B. Performance of group B on all 64 problems did not significantly change across problems. Apparently, blocks of eight problems were too short to permit the learning of which dimension was relevant. This same generalization holds for group A on the problems 33-64 that had not had a previously relevant dimension as their solution.

The immediate effect of pretraining was evaluated by comparing the proportion of relevant hypotheses offered by subgroups C_1 and C_4 during problems 1-8, with the proportion offered by subgroups C_2 and C_3. Note that for subgroups C_1 and C_4, the same dimension was relevant during pretraining and the first eight problems, while for subgroups C_2 and C_3 the relevant dimension differed. Strong effects were noted. When the same dimension was relevant in pretraining as was subsequently relevant during the first eight problems

(C_1 and C_4), the proportion of hypotheses fitting the relevant dimension was .656. When a different dimension was relevant (C_2 and C_3), the proportion was .063.

A similar analysis of the relevant hypothesis data on problems 25-32 for group C indicated no significant differences between subgroups C_1 and C_4 and subgroups C_2 and C_3. Thus, the effects of pretraining had disappeared.

Discussion

The fact that group A showed a significant problem sequence position effect while group B did not indicates that more than eight problems are necessary for a demonstrable learning set to develop. The difference between nonoutcome-problem sets suggests that the particular outcome problems received by subject may strongly affect the development of a learning set. Note that since the series of nonoutcome problems encountered by each nonoutcome group were outcome problems for the other nonoutcome group, different dimensional values were reinforced for the two groups.

The particular dimension relevant on problems 1-32 for the subgroups of group A did not result in significantly different learning-set curves. Thus, we may place more confidence in results of experiments done with only one relevant dimension. This result conforms to that of experiment 4, where it was found that sequential color-letter learning sets resulted in hypothesizing behavior similar to that found with letter-color learning sets.

The establishment of a learning set had a residual effect which was evident even after 24 problems in which the learning set was irrelevant. When the learning-set dimension again became relevant, a significant increase occurred from the first to the second nonoutcome problem in the number of relevant hypotheses. This increase did not occur unless a learning set had been established. Although subjects in group B had had experience with each relevant dimension during problems 1-32, no learning sets had developed, and no residual effects were noted during problems 33-64. Apparently, the probability of resampling a hypothesis increases due to learning sets for that hypothesis and this increased probability remains even after interpolated problems.

The residual effect of a learning set may explain the observation first made by Levine (1963) and replicated in experiment 4, that the first learning set resulted in a higher number of relevant hypotheses than the second. The first learning set may have increased the probability of retesting the hypothesis relevant to it, thereby decreasing the probability of testing the hypothesis relevant to the second learning set.

A final conclusion is that pretraining has strong but transitory effects on hypothesizing behavior. This would be expected from the observed residual effects of learning sets. Since only one pretraining problem was given, no learning set would have developed, and residual effects would not be anticipated.

Experiment 6 again points up certain regularities in hypothesizing behavior. Hypotheses are offered in a systematic predictable manner, apparently reflecting an attempt by subject to ascertain the correct cue for responding. Establishment of a learning set increases the probability that the hypothesis relevant to it will be tested, both immediately and on later problems similar to it.

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RETENTION AND CONCEPT IDENTIFICATION AS FUNCTIONS OF CONCEPT COMPLEXITY, METHOD OF PRESENTATION, STIMULUS EXPOSURE TIME, AND CONDITIONS OF RECALL

Abstract

48, 80, 48, and 80 students from introductory educational psychology classes participated in four consecutive experiments that were designed to ascertain whether certain stimulus variables and other conditions that supposedly impeded concept attainment because of increasing the memory load actually resulted in lower retention. Two stimulus variables manipulated in three of the four experiments were concept complexity--one or three relevant attributes comprising the concept, and method of presenting instances--simultaneous or successive presentation. The other variable manipulated in two of the four experiments was stimulus exposure time--5, 10, 15 seconds. Method of recall manipulated in two of the four experiments was unrestricted recall in which the subjects were to recall the instances and categories (whether the instance was or was not a member of the concept) in the order presented in the experiment, and random recall in which the subjects were to recall the instances and categories in a nonsequential random order fixed in advance by the experimenter. In the first three experiments the stimulus material consisted of four bi-valued dimensions: shape (triangle or rectangle), number (one or two), color (red or blue), and size (large or small). In the fourth experiment two other dimensions were included: position (right or left) and orientation of figures (upright or tilted). The dependent variables were concepts identified, values of instances recalled, and categories recalled.

The simultaneous method of presentation resulted in significantly better recall of instances and recall of categories in two of three and three of three experiments, respectively, as hypothesized. The unrestricted recall of instances and categories was significantly better in one of the two experiments and in the same hypothesized direction in the other. Stimulus exposure time of 5 seconds produced significantly poorer retention of instances and categories in two of two experiments as hypothesized. Complexity of the concept yielded mixed results in that in only one case was the three-relevant-attribute concept associated with significantly poorer recall. The other small differences generally were in the same hypothesized direction. In conclusion, the major contribution of these studies was to demonstrate for the first time that variables assumed to increase memory load, in fact, were associated with poorer retention scores. Moreover, the absolute level of recall under most conditions was sufficiently high to render questionable the limited memory assumption of various models of concept identification.

The results relating the same variables and conditions to concept attainment were less clear, although the tendency was in the hypothesized direction. Only the lower stimulus exposure time of 5 seconds

in comparison with 10 and 15, produced significantly poorer concept attainment in two of two experiments. Although the small means differences were always in the hypothesized direction, the method of presentation did not produce significant differences in concept attainment and in only one of three experiments did concepts of one-attribute complexity result in higher attainment than concepts of three-attribute complexity. The method of recall was not expected to affect concept attainment, however this variable did affect concept identification in one experiment. The most plausible explanation of the lack of effect of both concept complexity and method of presentation on concept attainment is that the stimulus material of four bi-valued dimensions was too easy. However, this cannot be positively asserted.

RETENTION AND CONCEPT IDENTIFICATION AS FUNCTIONS OF CONCEPT COMPLEXITY, METHOD OF PRESENTATION, STIMULUS EXPOSURE TIME, AND CONDITIONS OF RECALL[1]

The current status of our knowledge of the role of memory in concept learning is disappointing. In a review of the topic, Dominowski (1965) states that "... studies reported here have demonstrated to some degree the role of memory in the acquisition of concepts, but the precise identification of certain variables and their functional relationships with performance has not yet been achieved." One reason for the lack of information concerning the relationship between memory and concept identification must certainly be the scarcity of studies dealing explicitly with this topic. Of more than 500 studies in the area of concept learning reviewed by Klausmeier, Ramsay, Fredrick, and Davis (1965), less than 10 dealt with memory.

A further hindrance to our understanding of the role of memory in concept learning is the variability of experimental techniques and tasks employed in investigating this phenomenon. Some variation of experimental conditions is certainly needed in order to establish generality of our findings, however, variations of tasks conditions in an unsystematic fashion has more often than not led to confusion about the effects of a given variable.

The indirect nature of the evidence regarding the role of memory in concept identification is still another barrier to our understanding of this important phenomenon. For example, several studies (Bourne, Goldstein, and Link, 1964; Cahill and Hovland, 1960) have found that the successive method of presentation resulted in less efficient concept identification than did simultaneous methods of presentation. It was concluded that the less efficient performance was a result of the subject's failure to recall previously presented information. The information on memory provided by such studies is obviously limited in that no direct retention measures were used.

Yet another problem in understanding the role of memory in concept identification becomes apparent when one considers the various classes of information present in concept learning tasks. The different kinds of information which subjects may retain in concept identification are: (1) memory for the concept and its associated label once it has been

[1] This report is based on data collected by Gerald Miller for a Ph.D. dissertation conducted under Herbert J. Klausmeier during the academic year 1966-67. J. Kent Davis contributed substantially to the original conception and design of the experiments contained herein. The report was written by Elizabeth Schwenn and Herbert J. Klausmeier.

learned, (2) memory for the hypotheses which have been tested and those which remain to be tested, (3) memory for the characteristics, or attributes, of the instances which have been tested, and (4) memory for the category of the instance, i.e., whether or not a specific instance is a member of the concept. Although a number of experiments have assessed retention of concepts after learning (Oseas and Underwood, 1952; Richardson, 1956) few experiments have been concerned with retention of other classes of information during concept acquisition.

The problems listed above suggest at least two criteria for further experimentation in the area of memory and concept learning. First, experimentation should proceed within the confines of a standard task in order that the effects of the independent variables may be attributed to their manipulation and not to peculiarities of the tasks in which they are employed. Second, direct measures of retention should be employed in order to determine the extent to which retention of various classes of information influences concept identification. These criteria were considered in designing the present studies. In the present experiments four independent variables were selected which have been found to influence performance in both concept identification and memory tasks.

The first of these, concept complexity, can be defined either by the amount of relevant or irrelevant information present in the problem. Numerous studies (e.g., Archer, 1962; Archer, Bourne, and Brown, 1955; Bulgarella and Archer, 1962; Bourne, Goldstein, and Link, 1964) have found an inverse relationship between performance in concept identification and concept complexity. Other studies (Cahill and Hovland, 1960; Bourne, Goldstein, and Link, 1964) provide indirect evidence which suggests that memory factors may be, in part, determiners of complexity effects upon performance. The present studies manipulated concept complexity by varying the amount of relevant information. Moreover, both a retention and acquisition task were employed to allow a direct assessment of the effects of complexity upon memory and the degree to which memory is related to concept identification.

The second variable selected for investigation was method of presentation of instances, simultaneous or successive. In general, the evidence indicates that increasing the amount of information directly available for inspection increases the accuracy of the subject's hypotheses as well as decreases the number of trials required to solution (Bourne, Goldstein, and Link, 1964; Cahill and Hovland, 1960; Kates and Yudin, 1964). A reasonable assumption which has often been made is that by varying the method of presentation one is varying the availability of information and thus the efficiency with which information is retained. It was the intent of the present study to test this assumption directly.

A third variable investigated was that of stimulus exposure time. Previously mentioned studies have indicated that information, to be efficiently utilized, must either be sufficiently remembered or available for inspection. Whether stimuli are presented simultaneously or successively, or under some intermediate conditions, the temporal

interval for inspection ought to be a critical variable in determining both acquisition and retention efficiency.

Finally, in the experiments to be reported the conditions of recall were varied in terms of unrestricted or randomized recall order in order to determine the effects of this variable in retention. Within each of the experiments to be reported, two or three of the above variables were factorially combined to provide not only information on the main effects of the variables, but also on possible interaction effects. As mentioned previously, both acquisition (number of concepts identified) and retention (number of instance characteristics recalled, and number of instance categories recalled) were measured.

Experiment 7: Concept Complexity and Method of Presentation

Purpose

In this experiment concept complexity and method of instance presentation were varied in order to determine their effects on the recall of information presented in a concept identification task. It was assumed that the retention task employed reflected the degree to which the variables differentially affected information storage during the task. It was thought that the high-complexity concepts would be more difficult to identify than low-complexity concepts and that recall would be less efficient for high-complexity concepts. It was also hypothesized that both concept identification and recall would increase when instances were presented simultaneously as opposed to successively.

Subjects

The subjects were seven males and 41 females ranging in age from 18 through 23 years (mean age was 20.6).

Experimental Materials

The stimulus materials used to present the concepts consisted of geometric figures drawn on 3 inch by 5 inch index cards. Each figure represented a unique combination of the following four bi-valued dimensions: shape (triangle or rectangle), number (one or two), color (red or blue), size (large or small). A total of 16 cards was required to produce figures using all possible combinations of the values specified above. Each of the instance cards was labeled YES in six-point primary type. This designation was located at the bottom of each card. An identical set of 16 cards was constructed and each categorized NO in a similar manner.

The construction of the problems was similar for both levels of complexity (one value or three values relevant). Each problem contained five instances. The first instance was always labeled YES (positive instance). Between each of the subsequent four instances, one or two dimensions were varied subject to the restriction that only one dimension could be varied for the first time. This problem structure allowed

the subject to categorize a single dimension as relevant or irrelevant between any two adjacent instances.

Initially, eight problems were constructed within each of the two complexity levels. For the low-complexity problems (one value relevant), each of the eight values was used as the concept for a different problem. The high-complexity problems (three values relevant) were constructed such that each value was used in combination as part of the concept approximately equally often.

The test booklets used for recall contained two response pages for each problem. The first page contained the word "concept" followed by a line upon which the subject wrote a description of the value(s) comprising the concept. The second response page contained a coded description of each instance. Recall was performed by subjects circling an appropriate description of each dimension (e.g., color, <u>red</u> or <u>blue</u>; and category, <u>yes</u> or <u>no</u>).

The apparatus employed in this experiment consisted of a stimulus-card-display box and an automatic tape sequencer. The display box was a five-sided enclosure internally illuminated with three 75 watt showcase lamps. The back of the box contained a horizontal row of seven 2 3/4 inch by 4 3/4 inch apertures in which the instance cards could be displayed. The experimenter was seated in back of the box where he controlled the room lights, the display lights, and the tape sequences. The automatic tape sequencer was used to present the taped instructions, buzzer signals, and to control the presentation cycles for both methods of presentation.

<u>Experimental Procedure</u>

All subjects were tested in groups of three and were seated in a semi-circle facing the display box. The subjects were fully instructed as to the nature of their task and the procedure which they were to follow in completing their test booklets. Two practice problems were given during the instruction.

The procedure of displaying the instance cards was determined by the method of presentation employed. For the successive condition, only the center aperture of the display box was used. All five instances were inserted behind the aperture and withdrawn singly during each 5-second interstimulus interval. For the simultaneous conditions, all five instances were inserted into the five center apertures and shown simultaneously via a flap which covered or uncovered all cards instantaneously. The presentation time for the successive condition was held constant at 10 seconds for each instance. For the simultaneous condition all instances were displayed for 70 seconds. Thus, total time for problem presentation was held constant across methods of presentation.

The experimental design consisted of a 2 x 2 factorial combination of two levels of complexity (<u>one</u> or <u>three values</u> relevant) and two methods of stimulus presentation (<u>simultaneous</u> or <u>successive</u>). Twelve subjects were randomly assigned to each of the four methods by

complexity treatment combinations. In addition, for each of the four treatments, each group of three subjects was randomly assigned four concept problems. Consequently, each subject was tested on four problems within a single method by complexity treatment.

After each problem, the subject was required to write a description of the concept, and then to recall the four values of each instance and its category. Subjects were allowed 15 seconds to write their descriptions of the concept. A buzzer then sounded signaling a page turn. All instance descriptions were completed on the second page with a response time of 75 seconds allowed.

Results

The data used for analyses were the subjects' scores for each problem for each of the following dependent variables: concept score, scored either right (1) or wrong (0); recalled instance values (total possible range = 0-20); and recalled instance categories (range = 0-5). A repeated measures analysis of variance was performed on each of the three dependent variables indicated above. The procedure outlined by Box (1953) was employed to test all effects on which repeated measures occurred. The procedure reduces the degrees of freedom to $(a-1)\,\lambda$ and $(a-1)(n-1)\,\lambda$, where "a" is the number of levels of the repeated measure and λ is set at $1/a-1$. All effects in the series of experiments involving repeated measures were assessed by this conservative test.

Concept identification. Complexity was found to influence concept identification in the predicted fashion. The mean concept identification score per problem for the low-complexity subjects was .864; that for the high-complexity subjects was .635. The difference between these mean scores was significant ($F = 5.89$, $p < .05$). This and subsequent F tests, unless otherwise noted, were carried out with 1 and 44 degrees of freedom.

The method of instance presentation was not found to significantly influence concept identification. The mean numbers of concepts identified were .791 and .708 for the simultaneous and successive conditions respectively. Thus, while the difference was quite small it was in the expected direction.

While presentation method was not significant by itself, the efficiency with which concepts were identified was found to be dependent upon the particular method by complexity treatment combination. With concepts of low complexity, the successive method of presentation produced a mean of .92 concepts identified which was slightly better than the mean performance of .81 obtained with the simultaneous method. On the other hand, with high-complexity problems the simultaneous method with a mean of .77 was superior to the successive method which yielded a mean of .50. This interaction of method by complexity was found to be significant ($F = 4.79$, $p < .05$) Thus, with problems of high complexity the simultaneous method of presentation facilitated concept identification while with low-complexity problems there was little difference between presentation methods.

The ordinal position of the four problems was not found to affect concept identification nor any of the other dependent variables. That is, there was no indication that performance was affected by practice on similar problems. However, the interaction of ordinal position by method was significant in concept identification. Since the interaction involved repeated measures the conservative test was applied. Under the conservative test ($df = 1/44$) the effect was not significant. Since the observed F value was proximate to the lower bound of the questionable region specified by the reduced and unreduced degrees of freedom and since no interpretable trends were observed within each method level and across the four problems, no further analysis was deemed necessary.

Instance retention. The only significant sources of variation in the recall of instance values were complexity ($F = 10.41$, $p < .01$) and method ($F = 75.70$, $p < .01$). Both of these effects were in the predicted direction. Considering complexity first, the mean number of instance values correctly recalled for each low-complexity problem was 18.08 while that for the high-complexity problems was 16.84. The simultaneous method of presentation yielded a mean of 19.14 values recalled versus 15.79 for the successive method. While the relative recall performance under different conditions is of primary concern here, note that the absolute levels of recall were quite high under all conditions.

Category recall. Method of presentation was the only variable which significantly influenced the recall of categories. Again, the simultaneous method resulted in better performance with a mean of 4.92 versus 4.36 categories recalled under the successive method.

The effect of complexity upon category recall, while not significant, was in the expected direction with the low-complexity subjects ($M = 4.73$) recalling slightly more categories than the high-complexity subjects ($M = 4.56$). Again, note the high level of performance under all conditions.

Briefly summarizing the results of experiment 7, the low-complexity concepts produced more efficient recall of instances and better concept identification than did the high-complexity concepts. The simultaneous method of presentation produced both more efficient recall of values and categories and at least for the high-complexity concepts facilitated concept identification over the successive method. In conclusion, experiment 7 yielded suggestive evidence which tends to support the notion that when memory for the information presented in a concept identification task is facilitated, the efficiency of concept identification is increased.

Experiment 8: Concept Complexity, Method of Presentation, and Conditions of Recall

Purpose

The variables of concept complexity and presentation method were again manipulated in the second experiment and thus it served as a

replication of experiment 7. In addition the conditions of recall were manipulated in order to determine the effects of this variable upon concept identification and retention of instance values and categories.

Subjects

The subjects were 19 males and 61 females ranging in age from 18 through 25 years, the mean age was 21.9 years. All subjects participated on a voluntary basis and were drawn from two introductory educational psychology classes during the 1966 summer session.

Experimental Materials

All stimulus material and apparatus with the exception of the test booklets were as described in experiment 7. For the unrestricted recall condition the test booklets were the same as those employed in experiment 7. It will be recalled that these booklets contained two response pages for each problem. On the first page subject wrote a description of the concept. On the second page subject circled the dimension values and the category which described each instance. In the random recall condition the test booklet contained six response pages for each problem. The concept description page was identical to that described above. The next five pages contained coded descriptions of single instances along with the designation of the presentation position of the instance. For example, a subject might recall the instances in the following order: first, third, fourth, second and fifth. Recall was performed in a manner identical to that described for unrestricted recall. That is, values and categories were circled for each instance. The randomized recall test booklets were assembled using five randomly determined recall sequences.

Experimental Procedure

All subjects were tested in groups of five. The instructions and procedure were, for the most part, identical to those of experiment 7. In the unrestricted recall situation, subjects were instructed to complete the description of the instances in the order they were presented. The random recall situation required subjects to complete the instance descriptions in a specified order. Under both recall conditions, subjects were allowed 15 seconds to write their descriptions of the concept. Under the unrestricted condition all instance descriptions were completed on a single page within a 75 second time limit. Fifteen seconds were allowed for the completion of each random recall page.

A 2 x 2 x 2 factorial design was employed with two levels of concept complexity (one value or three values relevant), two methods of presentation (simultaneous or successive), and two conditions of recall (unrestricted or random). Each subject solved five problems selected at random within the appropriate complexity level. Each group of five subjects was randomly assigned to one of the eight treatment cells for a total of ten subjects in each condition.

Results

Each of the three dependent variables was scored as in experiment 7. Again each was tested within a repeated measures analysis of variance. The two conditions of recall were used in assessing concept identification so that any possible differential effects of conditions of recall upon subsequent identification of successive concepts could be determined. The mean numbers of concepts identified and instance values and categories recalled for all treatment conditions are found in Table 8.1.

Concept identification. The main effects of complexity and presentation method were not significant. However, the method used to present the instances produced identification performance in the hypothesized direction; namely, that the average number of identified concepts was greater under the simultaneous condition (.62) than that observed under the successive condition (.51). On the other hand, the means for the low- and high-complexity conditions were not in the expected direction. The mean number of concepts identified was .55 and .58 for the low- and high-complexity conditions respectively.

A statistically significant main effect was observed for conditions of recall ($F = 6.39$, $p < .05$) with 1 and 72 degrees of freedom used in this and subsequent tests. The interaction of complexity with recall was also significant ($F = 4.26$, $p < .05$).

The mean number of identified concepts within the unrestricted and random conditions was .675 and .455 respectively. This result indicated that the recall procedure significantly affected the efficiency of concept identification. Concepts were identified less well by the group receiving the random recall treatment. This statement, however, must be qualified because of the significant interaction involving complexity with recall. The interaction was such that concept identification under the high-complexity condition was not much affected by conditions of recall. However, performance on low-complexity concepts decreased markedly under the random recall condition.

Instance retention. The mean number of instance values retained under the low- and high-complexity conditions was 16.43 and 16.40 respectively. Thus, complexity was not a significant source of variance in instance retention. The variables of conditions of recall ($F = 13.94$, $p < .01$) and method of instance presentation ($F = 5.74$, $p < .05$) were found to have significant main effects.

The significant source of variation attributable to the conditions under which recall occurred was observed to be in the direction favoring unrestricted recall. The mean number of instance value retained was 17.25 and 15.58 under the unrestricted and random recall conditions respectively.

Method of instance presentation was also found to significantly affect recall. The means entering into the effect were 16.95 and 15.88 for the simultaneous and successive conditions respectively. This result

Table 8.1

Mean Number of Concepts Identified, Instance Values Recalled, and Categories Recalled for All Treatment Groups in Experiment 8

Conditions of Recall	Concept Complexity	Method of Presentation	Dependent Variables		
			Concepts Identified	Instance Values Recalled	Categories Recalled
Unrestricted	1-Value Relevant	Simultaneous	.78	18.28	4.88
		Successive	.72	16.94	4.18
	3-Value Relevant	Simultaneous	.60	17.04	4.60
		Successive	.60	16.74	4.26
Random	1-Value Relevant	Simultaneous	.44	15.92	4.34
		Successive	.26	14.56	3.84
	3-Value Relevant	Simultaneous	.66	16.56	4.50
		Successive	.46	15.26	4.02

indicates that subjects were better able to retain the values of the instances under conditions allowing maximum stimulus availability throughout problem presentation.

A further significant source of variation was contributed by the second order interaction of recall method by presentation method by ordinal position ($\underline{F}$ = 4.04, $\underline{df}$ = 4/288, $\underline{p}$ < .01) which was also found to be significant under the conservative test ($\underline{df}$ = 1/79). An inspection of the means entering into this effect did not show any readily interpretable patterns. Thus further consideration of such effects must await additional evidence on the influence of practice effects upon the task variables employed in the present study.

Category retention. Complexity did not produce significant differences in the number of categories correctly recalled. Both conditions of recall ($\underline{F}$ = 4.01, $\underline{p}$ < .05) and method of instance presentation ($\underline{F}$ = 10.99, $\underline{p}$ < .01) produced significant main effects, however. No interaction effects were found to be significant.

The mean number of categories recalled under the unrestricted and random conditions was 4.48 and 4.18 respectively. Inspection of the two means indicates that while recall of categories was greater when unrestricted rather than random recall procedures were employed, recall of categories was very high within both conditions of recall. This result was not unexpected in view of the relatively low information load within either of the two problem complexities. In any problem, the number of negative instances was identical to the number of relevant values comprising the concept. Consequently for low complexity concept problems (one value relevant), only the presentation position of the NO instance insured maximum category recall. Conversely, for high-complexity problems (three values relevant) the recall of the presentation positions of the two YES instances provided the sufficient condition for maximum category recall. The failure to find that the complexity of the problem significantly affected category recall offers partial support for this explanation.

The main effect of method of instance presentation was also found to significantly affect category retention. The mean number of categories recalled under the simultaneous and successive conditions was 4.58 and 4.08 respectively. Retention, therefore was more efficient under the simultaneous method of presentation which allowed maximum instance availability.

In summary, experiment 8 showed the simultaneous method of presentation and unrestricted recall conditions to result in superior recall of both instance values and categories. Although not statistically significant, the simultaneous method of presentation also tended to be related to more efficient concept identification. This, combined with the similar results of experiment 7 concerning method of presentation lends some support to the larger hypothesis underlying these studies that increased retention of information embodied in the instance is associated with more efficient concept identification.

The unrestricted condition of recall was also associated with more efficient concept identification suggesting that permitting the subject to recall instance values and categories without any recall order imposed by the experimenter facilitated identification. Why this should be the case however is not clear.

Contrary to the results of experiment 7, the complexity of the concept failed to differentially affect either concept identification or the recall of instances. It is difficult to account for this discrepancy since with respect to this variable the experiments employed identical task, instruction and procedural conditions. The next experiment was designed to further explore the effects of complexity along with other variables.

Experiment 9: Concept Complexity, Conditions of Recall, and Stimulus Exposure Time

Purpose

In the preceding experiments, both method of presentation and conditions of recall generally produced differences in concept identification and retention which were in the expected direction. The results for concept complexity were equivocal. In experiment 7 low complexity produced better identification and instance recall. This was not the case in experiment 8. Experiment 9 was designed to provide more information on this variable by determining whether the effect of complexity is related to the temporal duration employed to present the instances of the concept. For the purposes of not confounding exposure duration and presentation method, both of which affect the degree to which stimuli are available for subject's inspection, only the successive method of presentation was employed together with stimulus exposure times (SET) of 5, 10, and 15 seconds. The hypotheses tested in the present experiment were: (1) that the high-complexity concepts would be more difficult to identify than low-complexity concepts under successively lower SETs of 15, 10, and 5 seconds; (2) that the recall of instances and categories would be less efficient the shorter the SET, and (3) that concept identification and recall of instance values and categories would be less efficient under conditions employing random recall procedures.

Subjects

The subjects were 14 males and 34 females ranging in age from 18 through 25 years; the mean age was 20.9 years. All subjects participated on a voluntary basis and were drawn from two introductory educational psychology classes.

Experimental Materials

The stimulus materials were identical to those used in the previous experiments.

Experimental Procedure

All subjects were tested in groups of three using instructions similar to those in experiments 7 and 8, with the exception that only one practice problem was used. Only the successive method of presentation was employed in both practice and experimental problems. Each instance was displayed for 10 seconds in the practice problem; SETs of 5, 10 and 15 seconds were used in the experimental problems. For each group of subjects, six problems were randomly selected from each complexity level. The recall procedure was the same as employed previously.

A 2 x 2 x 3 factorial design was used with two levels of concept complexity (one or three relevant values) and two recall conditions (unrestricted or random), with repeated measures across three stimulus exposure times (5, 10, or 15 seconds). Each subject solved six problems, two within each exposure time interval with the restriction that each of the six exposure durations occupy a given ordinal position approximately equally often within any complexity by recall treatment combination.

Results

The scoring procedure differed from the previous experiments in that the problems were summed within each SET and used as the basic data. Each dependent variable was tested within a 2 x 2 x 3 repeated measures analysis of variance. The mean numbers of concepts identified and values and categories recalled for all conditions are found in Table 9.1.

Concept identification. Table 9.1 indicates the mean performance for two problems within each treatment condition. Again complexity was not a significant source of variation. As assessed by the conservative test (df = 1/44) the effect of SET was not significant although both the main effect of SET and the SET by recall method interaction approached the critical *F* value. The three means entering into the SET main effect were .94, 1.21, and 1.06 for the 5, 10, and 15-second conditions respectively. Thus there was some indication that more concepts were identified under the two conditions allowing exposure intervals in excess of 5 seconds although apparently the function relating SET to concept identification was not primarily linear.

Conditions of recall did not significantly affect the number of concepts identified.

Instance retention. Within the present design, the instance recall scores for the two problems which occurred within a given SET were summed and used as a single observation.

Main effects attributable to complexity and condition of recall were not significant. The mean numbers of instance values recalled were 30.08 and 30.58 for the low-and high-complexity conditions respectively. The unrestricted recall condition yielded a mean of 31.61 values recalled while the random condition produced a mean of 29.06.

Table 9.1

Mean Number of Concepts Identified, Instance Values Recalled and Categories Recalled for All Treatment Groups in Experiment 9

Conditions of Recall	Concept Complexity	Stimulus Exposure Time	Dependent Variables: Concepts Identified	Instance Values	Categories
Unrestricted	1-Value	5 second	.92	29.8	7.7
		10 second	1.33	32.4	8.3
		15 second	.92	33.7	9.1
	3-Value	5 second	.92	29.0	8.3
		10 second	1.33	31.7	8.5
		15 second	.92	33.1	8.8
Random	1-Value	5 second	.83	26.0	7.8
		10 second	1.17	29.9	7.8
		15 second	1.25	28.7	8.3
	3-Value	5 second	1.08	28.8	8.1
		10 second	1.00	29.0	6.8
		15 second	1.17	32.0	8.3

The main effect of SET was statistically significant ($F = 12.10$, $df = 2/88$, $p < .01$). Since SET involved repeated measures across three instance-exposure intervals, the conservative test was applied. Under the conservative test the effect was again statistically significant ($F = 12.10$, $df = 1/47$, $p < .01$). No interactions were found to be significant. The mean numbers of values recalled were 28.40, 30.75, and 31.85 for the 5-, 10-, and 15-second conditions respectively. A subsequent analysis of trend indicated that the linear component was significant ($F = 23.46$, $df = 1/47$, $p < .01$). Thus, recall performance increased as a direct linear function of time available for viewing the instances.

Category retention. As with instance-value recall, the category performance scores for each subject were summed across the two problems presented within each SET condition. The single effect found to be significant was attributable to SET ($F = 4.82$, $df = 2/88$, $p < .05$). Under the conservative test ($df = 1/47$) the effect was again significant. The mean numbers of categories recalled for two problems were 7.98, 7.88, and 8.65 within the 5-, 10-, and 15-second conditions respectively. A trend analysis indicated that the linear component was significant ($F = 6.30$, $df = 1/47$, $p < .05$). Thus, the number of categories recalled generally increased with increasing amounts of stimulus exposure time.

In the present experiment, concept complexity was again found not to differentially affect either concept identification or the recall of instance values and categories. Also, condition of recall was found not to affect any of the dependent variables. However, the direction of the means was similar for recall of both instance values and categories; namely, that the unrestricted recall condition was associated with more efficient recall of both values and categories.

As hypothesized, the recall of both instances and categories was found to be positively associated with increasing amounts of exposure time. For both values and categories, this relationship was primarily linear. Further, concept identification tended to be related to SET but the effect only approached significance.

Experiment 10: Method of Presentation, Stimulus Exposure Time, and Limited Memory Assumptions

Purpose

The results of the previous experiments, while not in complete agreement, have indicated that method of presentation, condition of recall, and stimulus exposure time significantly influenced the recall of instance values and categories. Superior recall resulted when instances were simultaneously presented and when instances were displayed for longer temporal durations. Moreover, it was generally the case that under conditions of simultaneous presentation and longer SET the concept identification performance was higher. However, in none of the preceding experiments have the effects of these variables on concept identification reached statistically significant levels. At this point it can only be stated that there is a trend in the data reported thus

far which supports the notion that conditions which facilitate retention also facilitate concept identification.

The results of the first three experiments suggest that within the conditions employed, memory was of greater importance in concept identification than is assumed by certain models of concept identification (Bower and Trabasso, 1963; Restle, 1962). The essentials of these investigators' position regarding the role of memory in concept identification are as follows: (1) each concept identification task dictates a finite number of possible solutions or hypothesis; (2) subject randomly samples and maintains a hypothesis until a negative instance is encountered; (3) in the case of a negative instance subject returns the hypothesis to the set and randomly resamples (with replacement). Consequently the only information assumed to be retained during the task is the current "working hypothesis" and a few previous trials across which it has been correct. Trabasso and Bower (1964) using a simulated concept identification task, tested the assumptions of limited memory for specific information presented during the task. Using six bi-valued dimensions (one dimension relevant), successive presentation, a 5 second stimulus exposure time and randomized recall order, the investigators asked subjects to identify the concept and then to recall the information presented during the task. Their results indicated that an average of less than one value was recalled of the six presented within each instance. In the preceding experiments in which a wider range of conditions was employed a higher recall for instance values was found.

The purposes of experiment 10 were twofold: first to further investigate the effects of both stimulus-availability variables employed separately in the preceding experiments (method of presentation and stimulus exposure time); and second, to further determine the generality of that aspect of the limited memory assumption pertaining to the recall of instance values as tested by Trabasso and Bower. The resulting modifications in both stimulus materials and procedures will be noted subsequently. The modifications, however, permitted a more direct comparison of results between the present experiment and those of Trabasso and Bower as well as allowing further comparisons of the variables employed within a task similar to that used in experiments 7, 8, and 9 but involving a greater number of total dimensions and a greater number of instances used to present the concepts.

Subjects

Thirteen males and 67 females ranging in age from 18 through 27 years (mean = 22 years) participated in the experiment. The 80 subjects were selected on a voluntary basis from three educational psychology classes at the University of Wisconsin.

Experimental Materials

The stimulus materials were the same as in preceding experiments except that two dimensions, position of figures (right or left) and orientation of figures (upright or tilted), were added. The addition

of the two dimensions increased the card population to 128 instance cards (64 YES and 64 NO).

The procedures used in determining the concepts to be identified were also identical to those employed with the four-dimension set with the exception that only one-value relevant concepts were used. Each of the 12 values was used as the concept once in a problem series.

Since the retention task was performed only under random recall, the test booklets contained 12 randomized sequences of seven instances each. The test booklets used for each experimental session contained five different orders of the 12 sequences.

A 2 x 2 x 12 factorial design was employed with two levels of stimulus exposure time (5 or 15 seconds), two methods of instance presentation (simultaneous or successive), and 12 problems on which repeated measures were obtained. All subjects were run in groups of five and randomly assigned to one of the four major treatment groups.

Experimental Procedure

The procedure was similar to that of the previous experiments. Each five-subject group was fully instructed about the nature of their task and a practice problem was presented under the same method by SET condition in which the subjects were performing. For the successive 5-second-treatment condition, each instance was displayed for 5 seconds with a 5-second-interstimulus interval. Similarly within the successive 15-second condition, instances were displayed for 15 seconds with a 5-second-interstimulus interval. For the simultaneous-5-second and 15-second conditions, all instances were displayed for 65 seconds and 135 seconds respectively. For all groups, 10 seconds was allowed for completing the description of the concept and 15 seconds for the recall of each instance.

Results

The means for concept identification, value recall, and category recall for all conditions are found in Table 10.1.

Concept identification. The main effects found to be significant were SET ($\underline{F}$ = 4.96, $\underline{df}$ = 1/76, $\underline{p}$ < .05) and ordinal position ($\underline{F}$ = 3.00, $\underline{df}$ = 11/836, $\underline{p}$ < .01). Under the conservative test ($\underline{df}$ = 1/79), however, the ordinal position effect was found to be nonsignificant.

The two means involved in the significant SET main effect were .610 and .781 for the 5-second and 15-second conditions, respectively. Thus, 61.0% and 78.1% of the concepts were correctly identified within each of the two SET conditions.

Although the method of presentation was not statistically significant the means were in the expected direction. Under the simultaneous method an average of .785 concepts were identified; the mean for the successive presentation was .633.

Table 10.1

Mean Number of Concepts Identified, Instance Values Recalled and Categories Recalled for All Treatment Groups in Experiment 10

Stimulus Exposure Time	Method of Presentation	Concepts Identified	Dependent Variables Instance Values Recalled	Categories Recalled
5 seconds	Simultaneous	.63	29.19	5.78
	Successive	.583	29.31	5.67
15 seconds	Simultaneous	.879	34.85	6.56
	Successive	.683	31.43	5.87

Instance retention. The recall of instance values was assessed in the same manner as in previous experiments. The scoring procedure yielded a maximum of 42 recalled values for any given concept.

Significant main effects included SET ($F = 21.16$, $df = 1/76$, $p < .01$) and ordinal position ($F = 6.93$, $df = 11/836$, $p < .01$). Under the conservative test, ordinal position remained significant ($df = 1/79$, $p < .01$). The interaction of SET with Method was also a significant source of variability ($F = 4.40$, $df = 1/76$, $p < .05$).

The mean numbers of recalled values were 29.25 and 33.14 for the 5-second and 15-second conditions, respectively. Thus within the conditions of the present experiment, it may be concluded that the number of values recalled was, in part, dependent upon the amount of time that the instances were available for inspection.

Although presentation method was not significant the means were in the expected direction. The subjects in the simultaneous condition averaged 32.02 values recalled while under the successive method 30.37 values were retained.

Inspection of the means in Table 10.1 indicates the nature of the significant SET by method interaction. It can be seen that performance within the successive method differed little across the two SET conditions, while within the simultaneous condition performance showed a sizable increase as SET increased from 5 seconds to 15 seconds. Thus the effect of SET was dependent upon the method of presentation being much greater with the simultaneous method.

The interaction between method and SET further suggested a comparison of the results obtained in the present study with those reported by Trabasso and Bower (1964). Their findings suggested that subjects were recalling an average of less than one of the six values presented within each instance. Their results, however, were based upon a scoring procedure somewhat different from that employed in the present study. Based upon a correction factor for chance performance, the average probability of recalling one of the six values was .583. The obtained probability of .567 reported by the study was therefore used to determine the number of values actually recalled.

Similar analyses were performed upon two of the treatment groups entering into the interaction. The first group (successive-5 seconds) performed under conditions similar to those employed in the Trabasso and Bower study. The second group (simultaneous-15 seconds) performed within the optimal conditions employed in the present study. The calculated probabilities yielded an average of 2.37 and 3.91 values recalled within each instance for the two conditions respectively. Thus it would appear that the observed differences were attributable to the two different identification tasks employed and to the levels of the variables employed in the present study.

The significant main effect of ordinal position was due to a decrease in number of values recalled across position. Subsequent analyses of this function by orthogonal polynomials indicated that both the linear ($\underline{F} = 48.99$, $\underline{df} = 1/79$, $\underline{p} < .01$) and quadratic ($\underline{F} = 11.85$, $\underline{df} = 1/79$, $\underline{p} < .01$) components were significant. Thus it may be concluded that the number of values retained was primarily a decreasing curvilinear function of the amount of practice on similar problems.

Category retention. Due to the increased number of instances used to present the concept, "7" was the maximum score attainable.

The main effect of SET was significant ($\underline{F} = 8.00$, $\underline{df} = 1/76$, $\underline{p} < .01$) as were the main effects of Method ($\underline{F} = 5.49$, $\underline{df} = 1/76$, $\underline{p} < .05$) and ordinal position ($\underline{F} = 2.05$, $\underline{df} = 11/836$, $\underline{p} < .05$). When retested under the reduced degrees of freedom ($\underline{df} = 1/79$), the effect of ordinal position was nonsignificant.

The mean numbers of recalled categories were 5.73 and 6.21 for the 5-second and 15-second SET conditions respectively. Thus 82% and 89% of the total number of categories presented were recalled.

The mean number of categories recalled for the simultaneous and successive methods of instance presentation was 6.17 (88%) and 5.77 (83%) respectively. Thus, the upper and lower levels of both the SET and presentation method variables resulted in essentially the recall of similar amounts of information. Moreover, the high levels of recall evidenced under both method and SET conditions not only resulted in reduced variability of performance but also suggested a ceiling effect produced essentially by the minimal information required for near maximum category recall. These two factors were primarily the source of the finding that the two main effects operated independently to produce category performance differences. Thus, the interaction of method by SET found for values failed to occur for categories.

Summary and Discussion

The essential findings of the present study with respect to the four variables of complexity, presentation method, stimulus exposure time, and recall method were as follows:

1. Except in experiment 7, concept complexity was not found to differentially affect either concept identification or recall of instance values or categories. In the first experiment complexity was significantly related to concept identification and recall of values.

2. In none of the experiments was method of presentation significantly related to concept identification. However, in all cases the direction of the differences favored the simultaneous method. Category recall was always found to be better under the simultaneous method while in two out of three cases recall of instance values was significantly better under the simultaneous method.

3. Longer stimulus exposure time resulted in better recall of values and categories in experiment 9 while concept identification was not significantly affected. In experiment 10, concept identification and recall of instance values and categories were better under the longer exposure time.

4. Unrestricted conditions of recall resulted in better concept identification, instance value recall and category recall in experiment 9. In experiment 10 conditions of recall did not reliably influence any of these dependent variables; however, in every case the differences did favor the unrestricted recall condition.

The major hypothesis underlying the present series of experiments was that variables which facilitate the memory process within a concept identification task also facilitate concept identification. The results cited above provide qualified support for this hypothesis in that, in general, it was the case that the conditions which facilitated recall also tended to affect concept identification in the same manner.

This is not a conclusion which will surprise many students of concept learning. Furthermore, the evidence provided by the present experiments does not permit firm statements concerning the relation between the retention and concept identification measures. That is, the conclusion that certain variables which facilitate concept identification do so, at least partly, because they facilitate the memory component of the task, cannot be drawn from data showing only a covariation of response measures. Such a conclusion would probably not strike most investigators in the area of concept learning as unreasonable, however. The present experiments are valuable, nevertheless, because they do provide evidence that retention of various classes of information within a concept identification task is associated with certain independent variables which also influence concept identification performance. This relationship was only inferred in previous studies since direct retention measures were never taken.

The contradictory findings concerning complexity are somewhat puzzling. A number of studies in addition to the first experiment of the present study have found that as the amount of relevant information increases, acquisition performance decreases (see Bourne, 1966).

It is possible to argue that the reason for the nonsignificant complexity effect in experiments 8 and 9 is that the difference in difficulty between the two levels of complexity employed within the concept identification task was not sufficiently large to produce differences in performance. The argument is based upon the notion of "concept size"--the total number of relevant dimensions employed in a concept identification task. Glanzer, Huttenlocher and Clark (1963) suggested that complexity is at a maximum when the ratio of relevant dimensions to total dimensions is one to two. The complexity manipulations in the present experiments were based upon the ratios of one to four and three to four. When the ratio of relevant to total dimensions is less than one-half, the NO instances provide sufficient information to identify the concept in

that a NO instance indicates that the dimension just varied is relevant. In the present experiments, only one NO instance was used for one-value relevant concepts. Conversely, when the ratio is over one-half, the YES instances indicate that the dimension just varied is not relevant. In the present experiments, two YES instances were used for the three-value relevant concepts. The relative equivalence of the minimum sufficient information necessary to identify the concept may account for the failure of complexity to produce performance differences. The difficulty with this explanation is, of course, that complexity did produce significant results in experiment 7 which did not differ in operations or procedures in any important respect from the other two experiments. The suggestion that sampling error may account for the discrepancy between the experiments is not very tenable since the results for other variables common to the different experiments are in substantial agreement. Obviously, no reasonably satisfactory conclusion regarding the effects of complexity as manipulated in this study can be drawn.

Both presentation method and stimulus exposure time were more significantly associated with recall than with concept identification. While recall of instance values and categories was in most cases higher under the simultaneous method of presentation and with longer exposure times, it will be remembered that under all conditions of presentation and exposure time the absolute level of recall was quite high. Moreover, the absolute level of concept identification was quite high under all conditions. The suggestion is, of course, that the concept identification task employed in the present series of experiments was not sufficiently difficult for variations in such task variables as presentation method and exposure time to produce substantial differences in concept identification performance. This conclusion is supported at least for presentation method by the numerous studies which have found an effect of this variable in concept identification (see Bourne, 1966).

That recall was better under conditions of unrestricted recall than under random conditions is not surprising when the relative availability of cues in the recall situation is examined. Under the unrestricted recall method subjects had immediately available for any particular instance both sequential and dimensional cues from all previously recalled instances. Under the random method these cues were not available.

Finally, the results of all four experiments failed to support the limited memory assumption of Trabasso and Bower and others concerning the retention of information presented during the task. Recall of both values and categories remained at a level higher than that predicted by models employing such an assumption. It is suggested that, within the conditions and task employed in the present experiments, the limited memory assumption as it pertains to the recall of information presented during the task was not supported.

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COGNITIVE STYLE, CONCEPT IDENTIFICATION

AND LIMITED INFORMATION PROCESSING

Abstract

90, 80 and 256 subjects participated in three experiments which investigated the relationship between cognitive style, concept identification and limited information processing. In the last experiment, an additional purpose was to define cognitive style more precisely. In experiment 11, subjects were divided into three groups of 30 subjects on the basis of their scores on the Hidden Figures Test (HFT), which supposedly measures the degree to which subjects manifest an analytical or global cognitive style. Within each group of high-, medium-, and low-analytical subjects, the subjects were assigned to concept identification problems of either high complexity (five irrelevant bits of information), average complexity (three irrelevant bits), or low complexity (one irrelevant bit). The stimulus materials consisted of combinations of values from each of seven dimensions: letter (H or L), number of letters (<u>one</u> or <u>two</u>), size of letters (<u>large</u> or <u>small</u>), color of letters (<u>red</u> or <u>green</u>), orientation of letters (<u>upright</u> or <u>tilted</u>), horizontal position of letters (<u>left</u> or <u>right</u>), and vertical position of letters (<u>upper</u> or <u>lower</u>). The subject's tasks were to correctly categorize stimulus patterns in terms of combinations of two relevant attributes. The dependent variable was number of error to a criterion of 16 consecutively correct responses. The results indicated that an individual's cognitive style did influence his concept identification performance. High-analytical subjects made fewer errors than the middle-analytical subjects who in turn made fewer errors than the low-analytical subjects. Concept identification was also an inverse linear function of concept complexity. The cognitive style of the subject did not interact with problem complexity.

In experiment 12, subjects were divided into two groups of high-and low-analytical ability on the basis of scores on the HFT. All subjects were given the high-complexity problems of experiment 11. Two types of training were given to independent subgroups of subjects. Subjects in the prompted-training condition received 24 trials on which the correct response button was indicated prior to their response. The subjects in the verbalization training condition were required to describe all of the values in each of the stimulus patterns before responding. A third condition was a combination of prompted and verbalization training. Finally, subjects in the control condition received no prompting or verbalization. Both the task and dependent variable were the same as for experiment 11. The results again showed that high-analytical subjects made fewer errors in concept identification than subjects of low-analytical ability. Both the prompt-only training and the

verbal-only training conditions were superior to the control condition. However, the verbal-prompt group was no better than the control. Again, there was no interaction of cognitive style with type of training.

In experiment 13, the items of the HFT were analyzed to determine the factors which underlie performance on this cognitive style test. The ratio of relevant to irrelevant information was found to correlate well with item difficulty. From this it may be inferred that attending to and discriminating between relevant and irrelevant information are important components of cognitive style. Subjects were also given tests of limited information processing (TIPT) and concept identification (CIP). The TIPT yields three scores which indicate whether the subject, given two cards following the focus card, correctly classifies the last instance, or test instance, as belonging to the same concept as the focus card, as not belonging to the same concept, or as indeterminate membership for lack of sufficient information. The results indicated that analytical subjects were superior to non-analytical subjects in the ability to process information and attain concepts.

COGNITIVE STYLE, CONCEPT IDENTIFICATION

AND LIMITED INFORMATION PROCESSING[1]

It is well documented that there are large individual differences in the manner in which people perceive and analyze a complex stimulus configuration and that this particular manner or style carries over into other areas of cognitive functioning. Furthermore, there is a growing body of literature which suggests that individual differences in perceptual and conceptual organization are relatively stable and interact to produce consistencies in cognitive functioning.

The term cognitive style has been used to refer to individual consistencies in cognitive behavior resulting from the individual's perceptual and conceptual organization of the external environment (Kagan, Moss, and Sigel, 1963). Various other terms such as cognitive control, cognitive system-principles, and perceptual attitudes have been used to label essentially the same phenomenon.

A number of different dimensions have been suggested within the rather general domain of cognitive style. There is one characteristic, however, which is common to a number of these dimensions. Although various labels are applied to this characteristic, it is concerned primarily with the manner in which an individual perceives and analyzes a complex stimulus configuration. The two poles of this dimension consist of subjects who analyze and differentiate the components of the stimulus complex and of subjects who fail to analyze and differentiate the components and respond to the "stimulus-as-a-whole." Kagan et al. (1963) classified the former subjects as analytical and the latter as relational and believed that their classification system was similar to the field independent-dependent classification of Witkin, Lewis, Hertzman, Machover, Meissner, and Wapner (1954). A similar classification system was suggested by Gardner (1953) in which the continuum was described as ranging from differentiated subjects to undifferentiated subjects. Thus, there appears to be one dimension which involves an active analysis on the one hand and a more passive, global acceptance of the entire stimulus on the other hand.

Although previous interest in cognitive style has focused essentially on the relationships between cognitive style and

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[1]This report is based on the Ph.D. dissertations of J. Kent Davis (experiments 11 and 12) and Wayne Fredrick (experiment 13). The research was conducted during the first semester of the academic year 1966-67 under the direction of Herbert J. Klausmeier. This report was written by Elizabeth Schwenn and Herbert J. Klausmeier.

personality structures and certain demographic relationships, it has been suggested that cognitive style has wide implications for a variety of areas including education (Witkin, 1965). The data from a number of studies concerned with cognitive style suggest that a person's cognitive style influences the quality of cognitive products involved in a variety of tasks such as paired-associate tasks (Kagan et al. 1963), memory tasks (Gardner and Long, 1961) vigilance tasks (Kagan et al. 1963), and problem-solving tasks (Witkin, 1964). A study by Baggaley (1955) suggested that cognitive style was also a significant variable in concept identification. In this study, subjects were presented cards that varied along five bi-valued dimensions and were asked to identify two dimensions which were relevant to classifying the cards. Baggaley found that subjects who performed in an analytic manner on the Concealed Figures Test also performed significantly better on the concept identification task than did subjects who performed in a more global manner on the Concealed Figures Test.

Since the majority of concept identification tasks require selective attention to relevant aspects of complex stimulus configurations, it would seem that further research on the nature of cognitive style in concept identification is necessary. The present experiments were designed to examine further the extent to which an individual's cognitive style influences his performance on a standard concept identification task. The operational index of the analytic-global dimension of cognitive style employed in the present studies was performance on the Hidden Figures Test (HFT).

The first study was designed to consider the relationship between cognitive style and performance on concept identification problems of varying levels of complexity. The purpose of the second experiment was to determine to what extent training procedures would facilitate the identification of concepts of analytic and nonanalytic subjects. The third experiment was an attempt to explore the factors underlying the positive correlation between cognitive style and concept identification.

Experiment 11: Cognitive Style, Concept Complexity, and Problem Type

Purpose

The purpose of this experiment was to examine the extent to which an individual's cognitive style influenced his performance on concept identification problems of varying levels of complexity. Cognitive style was operationally defined in terms of an individual's performance on the Hidden Figures Test (HFT). It was assumed that subjects able to identify the hidden figures represented an analytical cognitive style, while subjects unable to identify the hidden figures represented a global cognitive style. It was hypothesized that analytical subjects would experience less

difficulty in concept identification than would the global subjects. It was also hypothesized that the global subjects would experience greater difficulty with the more complex concepts.

Subjects

Three non-overlapping groups of 30 subjects each were selected from a distribution of HFT scores obtained from 310 senior high school males. One group, the high analytic scorers, consisted of subjects who experienced little difficulty on the HFT (scores ranged from 27.00 to 37.00). Another group, the low analytic scorers, consisted of subjects who experienced great difficulty on the HFT (scores ranged from 1.00 to 8.00). The third group, middle analytic scorers, consisted of subjects having scores on the HFT which were intermediate in their test performance (scores ranged from 17.00 to 18.25).

Experimental Materials

The stimulus patterns represented combinations of values from each of seven stimulus dimensions. The dimensions and their corresponding values were: letter (H or L), number of letters (one or two), size of letters (large or small), color of letters (red or green), orientation of letters (upright or tilted), horizontal position of letters (left or right), and vertical position of letters (upper or lower). The total number of unique stimulus patterns was 128, since each pattern represented only one value from each of the seven dimensions. These patterns served as a population from which the three levels of complexity and the two problems utilized in the experiment were constructed.

Complexity was defined in terms of the number of bits of irrelevant information contained within a problem. The three complexity levels were determined by designating one, three or five dimensions as irrelevant. Thus, in the 1-bit condition there were three dimensions which varied--the two relevant dimensions and one irrelevant dimension. In the 3-bit condition there were five dimensions which varied--the two relevant dimensions and three irrelevant dimensions. In the 5-bit condition all seven dimensions varied--two relevant dimensions and five irrelevant dimensions.

The apparatus consisted of three units: a four-channel response unit, a tape-reader unit and a slide projector. The four-channel response unit housed all of the electronic circuitry which controlled the sequence of events and registered subjects' responses. When the first stimulus slide was projected onto a screen, four response buttons located on the front of the response unit were illuminated. When subject pressed one of these response buttons, the appropriate feedback light(s) was illuminated, the 35 mm tape advanced in the tape-reader unit, the response recorded, and the next slide projected. The tape-reader unit consisted of four photocells and a 35 mm film sprocket which was driven by a motor

at the rate of 4 rpm. Holes were punched on a continuous loop of exposed 35 mm film which synchronized the feedback lights with the corresponding slide. A Kodak Carousel slide projector was employed to present the stimulus slide to the subject. The slide projector was situated on a platform 9 1/2 inches above the table and approximately 3 1/2 feet behind the response unit. The slides when projected onto the 15 x 12 inch screen were at about eye level of the subject.

Experimental Procedure

The procedure followed in the present experiment was similar to that outlined in Bourne (1957). The subjects were fully instructed as to the nature of the problem, the operation of the apparatus, and the criterion of the problem which was 16 consecutive correct responses.

During the experiment the subject was presented a series of stimulus patterns which corresponded to one of the three complexity levels and which was within the limits of one of the two basic problems. When a stimulus pattern was projected onto the screen, the subject was required to press one of four response buttons in order to determine the category to which that particular pattern belonged. The subject responded to each stimulus pattern by pressing one of the four response buttons mounted at the bottom of the response unit. If the response was correct, a green light was turned on above that response button. If the response was incorrect a red light would come on above that response button and a green light would come on above the correct response button. The significance of each button was therefore determined by trial and error. Each response button represented one of the four possible combinations of the two dimensions which were relevant to the solution of the problem.

The independent variables given consideration in the present experiment were task complexity, cognitive style, and problems. Three levels of task complexity (1, 3, and 5 bits of irrelevant information), three levels of cognitive style (high analytic, middle analytic, and low analytic), and two problems differing with respect to the two relevant dimensions (Problem A and Problem B) were factorially combined to form a 3 x 3 x 2 design. Five subjects from each of the three levels of cognitive style were randomly assigned to the problem by complexity level treatment conditions.

Results

Three response measures were obtained: total trials-to-criterion, total errors-to-criterion, and total time-to-criterion. Product moment correlation coefficients were computed between each of the response measures. The correlation between errors-to-criterion and trials-to-criterion was .957; between errors-to-criterion and time-to-criterion, .890; and between trials-to-criterion and time-to-criterion, .892. Only the data based on errors-to-criterion will be reported since the correlations between the response measures are strongly positive and because the instructions stressed accuracy rather than speed. Also, analyses of variance based on trials-to-criterion and time-to-criterion

gave essentially identical results as the analysis of variance on errors-to-criterion.

The analysis of variance on errors-to-criterion showed that the main effect of cognitive style was significant ($F = 9.51$, $df = 2/72$, $p < .01$), as were the main effects of complexity ($F = 18.31$, $df = 2/72$, $p < .01$), and problems ($F = 20.73$, $df = 1/72$, $p < .01$). Also significant were two interactions: Cognitive by problem interaction ($F = 4.94$, $df = 2/72$, $p < .01$) and complexity by problems ($F = 5.82$, $df = 2/72$, $p < .01$).

Table 11.1 presents the mean errors-to-criterion for cognitive style and problems. The significant main effect of Problems merely indicates that performance is dependent upon the particular dimensions relevant to problem solution. As can be seen in Table 11.1, subjects solving Problem B committed fewer errors than subjects solving Problem A at each level of cognitive style. Furthermore, it should be noted that the high-analytic subjects made fewer errors than the middle-analytic subjects who in turn made fewer errors than the low-analytic subjects and that this trend was consistent across both problems.

Table 11.1

Mean Errors-to-Criterion as a Function of Cognitive Style and Problems

	Cognitive Style			
Problems	High	Middle	Low	Mean
A	31.60	50.00	86.60	56.07
B	25.13	26.13	33.67	28.31
Mean	28.37	38.07	60.13	

Subsequent analysis of the cognitive style by problem interaction involved mean comparisons between cognitive style levels for each problem separately. For Problem A, the F test between cognitive style means was significant ($F = 8.57$, $df = 2/72$, $p < .01$). Furthermore, it was found that high-analytic subjects and middle-analytic subjects differed significantly from the low-analytic subjects ($t = 5.21$ and $t = 3.46$ respectively, $df = 72$, $p < .01$), but that the middle-and high-analytic subjects did not differ significantly from one another ($t = 1.74$). For Problem B, the F test between cognitive style means was not significant ($F < 1$). Thus, it may be concluded that an individual's cognitive style significantly influences concept identification, but only when the conditions employed for Problem A are met.

The significant main effect of problems was an unexpected finding. Subjects found Problem B, in which size and horizontal position were the relevant dimensions, easier to solve than Problem A, in which letter and letter orientation were the relevant dimensions. The mean number of errors-to-criterion for Problem B was 28.31 while the mean number of errors for Problem A was 56.07.

The significant main effect of complexity indicated that errors in concept identification were an increasing function of the complexity of the concept identification problems. An orthogonal polynomial analysis applied to this function indicated that the linear component of variation was significant ($\underline{F}$ = 36.33, $\underline{df}$ = 1/72, $\underline{p}$ < .01).

The individual cell means for the complexity by problem interaction are presented in Table 11.2. It can be seen that the number of errors-to-criterion for both problems increases linearly with increases in complexity. The rate of increase for Problem A, however, is greater than for Problem B. Subsequent analysis of this interaction involved

Table 11.2

Mean Errors-to-Criterion as a Function of Complexity and Problems

	Complexity			
Problems	1	3	5	Mean
A	22.20	53.33	92.67	56.07
B	19.53	26.33	39.07	28.31
Mean	20.87	39.83	65.87	

an orthogonal polynomial analysis and indicated that the linear component of variation was significant ($\underline{F}$ = 11.63, $\underline{df}$ = 1/72, $\underline{p}$ < .01). Thus, the interaction results from differences between the linear trends of the two problems across the levels of complexity.

Discussion

As hypothesized, an individual's cognitive style was found to influence his concept identification performance. Individuals identified as analytical on the HFT experienced little difficulty in identifying concepts while the global subjects who experienced difficulty in locating the simple figures in the HFT experienced considerable difficulty in concept identification. Individuals falling in the middle of the HFT distribution performed at an intermediate level of performance on the concept identification task. These findings further support the observation of Baggaley (1955) who found that analytic subjects were more successful than nonanalytic subjects in a concept sorting task. Similar findings have been reported by Ohnmacht (1966), Elkind, Loegler, and Go (1963).

Although it was found that performance was a decreasing function of the complexity of the concept identification problems, the hypothesized interaction between cognitive style and complexity was not supported by the data.

Experiment 12: Cognitive Style, Prompted Training, Verbalization Training, and Problem Type

Purpose

The purpose of this experiment was to determine whether the deficit in concept identification by the low analytic subjects in experiment 11 could be overcome through the use of training procedures. It was hypothesized that the training procedures would facilitate concept identification for all subjects, but that the degree of facilitation would be greater for the nonanalytic subjects.

Subjects

The HFT was administered to 323 senior high school males. Forty students from the analytic end of the distribution (scores ranged from 27-37) and 40 students from the nonanalytic end of the distribution (scores ranged from 2 to 11) were selected for the experiment proper.

Experimental Materials

The stimulus materials were the same as those used in experiment 11 with the exception that only one level of complexity was used (5 bits of irrelevant information).

Experimental Procedure

With the following exception, the procedure was identical to that described for experiment 11. Subjects receiving the prompted training were instructed that for the first 24 trials the correct response button would be illuminated prior to their response. They were further instructed that they could examine the stimulus pattern for as long as necessary before responding. Subjects proceeded in this fashion until 24 patterns had been presented. Following the 24 prompted trials, the subjects proceeded in a trial-and-error fashion until the criterion of 16 consecutively correct responses was reached.

Subjects receiving the verbalization training were instructed to describe all of the values present in each of the stimulus patterns before responding. In the event that a subject failed to identify all seven values, the experimenter indicated to the subject that he had omitted one or more of the values. Then, if the subject could not remember a value the experimenter would tell him. Subjects continued to name all of the stimulus values on every trial until reaching criterion.

The experimental design consisted of two levels of cognitive style (high or low analytic), two levels of prompted training (24 prompted trials or no prompted trials), two levels of verbal training (verbalization of all values per instance or no verbalization), and two problems which were factorially combined to form a 2 x 2 x 2 x 2 design. Ten subjects from each level of cognitive style were randomly assigned to one of four training conditions. The four training conditions were: a verbal-prompt condition, a verbal-only condition, a prompt-only condition, and a control condition which received no prompting or verbalization.

Results

Since subjects in the prompt conditions made no errors during the first 24 trials, the errors-to-criterion measure was computed for all subjects beginning with trial 25. The analysis of variance on errors-to-criterion indicated that the main effect of cognitive style was significant ($\underline{F} = 9.77$, $\underline{df} = 1/64$, $\underline{p} < .05$), as was the interaction of prompted training by verbal training ($\underline{F} = 10.05$, $\underline{df} = 1/64$, $\underline{p} < .05$).

The significant main effect of cognitive style indicated that high-analytic subjects committed fewer errors in identifying the concepts than did low-analytic subjects. The mean number of errors for the high- and low-analytic subjects was 41.72 and 66.87, respectively. The significance of the cognitive style source of variance is consistent with the results of experiment 11, and indicates that performance in concept identification is related to the ability to identify embedded figures in the HFT--subjects who experience difficulty on the HFT also experience difficulty in concept identification.

Table 12.1 presents the means involved in the significant prompted training by verbal training interaction. Subsequent analyses of the difference between the cell means revealed that the prompt-only condition

Table 12.1

Mean Errors-to-Criterion as a Function of Prompted Training and Verbal Training

	Prompted Training		
Verbal Training	Prompt	No Prompt	Mean
Verbalization	61.80	49.10	55.45
No Verbalization	34.00	72.30	53.15
Mean	42.90	60.70	

and the verbal-only condition differed significantly from the control condition ($\underline{t} = 3.37$ and $\underline{t} = 2.04$ respectively, $\underline{df} = 64$, $\underline{p} < .05$), but the verbal-prompt conditions did not differ significantly from the control condition ($\underline{t} < 1$). These results permit the conclusion that either verbal training or prompted training lead to superior concept identification, but when both training procedures are employed (verbal-prompt condition) performance does not differ from the control condition (no training).

Discussion

Individuals identified as high analytic solved the concept identification problem with greater ease than did the low-analytic subjects. These results are in agreement with the findings of experiment 11.

Thus it may be concluded that performance in concept identification is related to the ability to identify embedded figures in the HFT. Based upon the cognitive style literature, it may be suggested that subjects who experience difficulty in separating a simple geometric pattern from an embedding context also experience difficulty in separating relevant from irrelevant dimensions in concept identification. Several other alternatives, however, can be advanced to account for the low-analytic subjects' difficulty in concept identification. First, it is possible that low-analytic subjects are unable to remember individual instances as well as high-analytic subjects. Second, it may be that low-analytic subjects are unable to utilize feedback, to process information, or to test hypotheses as effectively as high-analytic subjects. The explicit reason for this difficulty, however, must await further research.

It was found that subjects required to verbalize (verbal-only condition) the stimulus values which were present in each stimulus pattern, identified the concept with fewer errors than subjects who did not verbalize the stimulus values (control condition). It may be that verbalization insures that a subject will not forget or overlook any of the stimulus dimensions or it may be that verbalization forces the subject to differentiate the relevant variables of stimulation as Tighe and Tighe (1966) suggested.

It was also found that subjects who received prompted training (prompt-only condition) identified the concept with fewer errors than subjects who did not receive prompted training (control condition). As in the verbal-only condition, it may be suggested that the prompt-only condition aids concept identification by reducing the memory requirements of the task and by providing an optimum amount of time for information processing. In the absence of a prompt the subject does not know which category is correct until after he has responded. Thus, he must respond and, in a relatively short interval, associate the correct category with the values of that instance. Subjects receiving the prompt-only condition, however, know which category is correct and therefore have an unlimited amount of time to associate the category with the values of that instance.

Since the verbal-only and the prompt-only training procedures were found to facilitate concept learning, it would be expected that combining verbal and prompted training would result in greatly facilitated performance. It was observed, however, that verbalization before the correct category was known (verbal-only condition) aided or facilitated concept identification, but that verbalization after the correct category was known (verbal-prompt condition) did not facilitate concept identification The reason for this poor performance, however, is not at all clear.

The failure to find any significant interactions involving cognitive style and either or both of the training procedures leads to the conclusion that these training procedures do not differentially influence concept identification for individuals manifesting different cognitive styles.

Both experiments 11 and 12 have shown that cognitive style is significantly related to concept identification. The purpose of experiment 13 was to explore factors underlying this correlation. More specifically, the relationship between concept identification, information processing and field articulation was sought.

Experiment 13: Cognitive Style and Limited Information Processing

Purpose

Recently Gardner, Jackson and Messick (1960) have stated that the selective attention to relevant versus compelling irrelevant stimuli may be the key to effective performance in tests using hidden figures. Selective attention also seems to be needed in concept identification in the separation of relevant from irrelevant information.

Concept learning is not a unitary ability, but is made up of several processes including limited information processing (Tagatz, 1963; Lemke, Klausmeier and Harris, 1967). There is the suggestion that ways of processing information correspond roughly to the global and analytical style in articulating the field (Tagatz, Lemke, and Meinke, 1966). In the present experiment data was gathered on concept identification and limited information processing as a function of the subject's level of field articulation. It was hypothesized that differences would appear in the difficulty of items in a test of cognitive style on the basis of the amount of relevant and irrelevant information involved in the item. Individual differences in ability to handle items of the cognitive style test would be reflected in information processing ability. That is, subjects who can articulate the field will also do well in the processing of information, and since information processing is part of the concept identification task, these "articulate" and analytic subjects would be expected to form more accurate concepts than the less articulate, global subjects. In addition, the subjects were sampled from various age levels so that the relationship among the above variables could be charted as a function of age as well as other subject characteristics, such as sex and IQ.

Subjects

The subjects used were 128 boys and 128 girls from three Wisconsin schools. There were 88 sixth graders, 82 eighth graders, and 86 tenth graders. The average IQ of the 256 subjects was 108.

Experimental Materials

The materials used were three tests, the Hidden Figures Test (HFT), the Tagatz Information Processing Test (TIPT), and Concept Learning Problems (CLP). The HFT is described in experiment 11. Only Part I (16 items) of the HFT was used.

Part I of the TIPT consisting of 30 items was used. In each item there was a focus card made up of six bi-valued dimensions and two other cards also made up of these six dimensions. Of these latter two cards, one was marked either YES or NO, and the other was marked with a question mark. The task of the subject was to decide whether the card marked "?" was a "YES" card, a "NO" card, or whether he hadn't sufficient information to decide (i.e., "Can't Tell"). Presumably the subject makes the decision by processing the information given to him by the focus card and the second YES or NO card.

The CLP consisted of two stories from which the subjects could learn (#1) which plants would be good to eat and (#2) which animals would bite. As in the TIPT, the plants and animals were made up of bi-valued dimensions. The plants consisted of four dimensions, of which two were relevant to defining the set of plants good to eat. The animals consisted of seven dimensions, of which two were relevant for defining the set of animals that would bite. The plant concept was considered the low-irrelevant-information problem. The task of the subject was to categorize new instances of the plants and animals. The test consisted of 24 items (12 items in #1 and 12 in #2). The dependent measures provided by the CLP included instances correctly categorized and inclusion and exclusion errors. All tests were contained in a test booklet which each subject received.

Experimental Procedure

The actual test procedure was the same for the three grade levels. The tests were given to large groups with the same experimenter in charge of each testing session. After the test booklets were handed out to all subjects of a particular grade, the subjects were requested to write their name at the top of the HFT and their name and sex on the first page of the TIPT-CLP booklet. The subjects were asked to give their most recent report card grade for English, social studies, and mathematics. The instructions for the HFT were read aloud to the subjects. The subjects were told to answer every item and to go from item to item when the experimenter gave the signal. Forty-five seconds were allowed for each item. After the HFT the subjects rested for one minute. Instructions for the TIPT were then administered.

Again subjects were instructed to answer every item and were paced at 20 seconds per item. Another one-minute rest period followed the TIPT. The instructions for the first CLP problem were then read aloud. The subjects were allowed two minutes to look at the six examples of YES and NO plants. They were then told to turn the page and not look back at the examples, and to begin item number one. The 12 items took three minutes, being paced at 15 seconds per item. The second CLP was immediately begun following the last item in CLP #1. The study and pacing times were the same as for the first CLP problem. The test booklets were then collected and subjects were dismissed.

Results

Item analysis. The HFT, TIPT and the CLP were each analyzed using the Generalized Item and Test Analysis Program (Baker, 1966). From the host of summary statistics provided by this analysis only the mean, standard deviation and internal consistency reliability of the three tests will be reported here.

The mean number of correct responses on the HFT was 5.75 with a standard deviation of 2.60. The Hoyt internal consistency reliability measure was .496. The F ratio of individual variance to error variance was 1.99 which was significant at the .01 level (df = 255,3825). This significant F ratio showed that the HFT was sufficiently accurate to differentiate among individuals.

The mean number correct on the TIPT was 14.13 with a standard deviation of 4.61. The internal consistency reliability was .686. The large ratio of individual to error variance (F = 3.19) showed that the test discriminated well among subjects.

The mean correct on the CLP was 18.28 with a standard deviation of 3.04. The F for comparing individual to error variance was 2.87 which was significant at the .01 level. The internal reliability was .651.

Correlational analysis of the HFT. The HFT is purported to measure analytical ability. For one or more reasons the figure embedded in the pattern is difficult to find and the pattern must be carefully analyzed. It was the purpose of this correlational study of the HFT to determine what aspects of the figure-pattern complex were possible correlates of successful analysis. Fifteen measures of the items in the HFT were obtained. These measures were the number of intersections in each pattern, the area of the figure, the number of closed figures in the pattern, and other similar measures. Other measures were ratios of relevant and irrelevant information. One measure was a combination of all the measures that involved the amount of relevant information.

The 15 measures of each item were tabulated and entered in columns as shown in Table 13.1. The total numbers of subjects who got each item correct were obtained and entered in the same table. The total numbers were divided into subtotals for males and females; sixth, eighth, and tenth graders; and high and low scorers. These subtotals were the eight dependent measures which were correlated with the 15 independent measures of items. The resulting correlations are listed in Table 13.1. Correlations of .50 or higher were significant at the five per cent level.

Of the 15 measures of the HFT items (a) two measures of the amounts of relevant information (measures 10 and 17) correlated .33 and .47 with item difficulty; (b) five measures of irrelevant information (11, 12, 18, 20, 21) correlated -.09, -.34, .01, .10 and -.29 with item difficulty; (c) three ratios of relevant to irrelevant information (13, 14, and 19) correlated .31, .43, and .32 with item difficulty; and (d) a combination of measures in (a) and (c) correlated .50. The performance of sixth grade high-HFT scorers was more sensitive to the measures in a, b, c and d than were the high eighth graders who in turn were more sensitive to these measures than high tenth graders. The grade difference could be interpreted as a gradual decrease with increasing age in the dependence of information processing upon absolute and relative amounts of relevant and irrelevant information. Males and females reacted similarly to a, b, c and d, but the performance of low-HFT subjects was different from high subjects in that it correlated only with a measure of relevant area.

Correlational study of IQ, GPA, and the three tests. Eight variables were selected for a correlational study. The eight variables were IQ; GPA in each of English, social studies, and math; and scores on the HFT, the TIPT and the CLP. Also included was total GPA. These

Table 13.1

Correlations of the Quantifications of the Items of the HFT
with the Group Performance Measures

Independent Variable	Group 1 6^{th}	2 8^{th}	3 10^{th}	4 Male	5 Female	6 High	7 Low	8 All
9. Number of the Item	.02	-.04	-.16	-.08	-.07	-.17	.10	-.08
10. No. of lines in figure	.41	.35	.08	.26	.34	.36	.19	.33
11. No. of closed figures in pattern	-.40	.01	.12	-.07	-.10	-.16	.05	-.09
12. No. of lines in pattern	-.50	-.31	-.06	-.28	-.34	-.42	-.11	-.34
13. Ratio of 10 to 11	.58	.26	-.01	.18	.37	.35	.15	.31
14. Ratio of 10 to 12	.56	.44	.09	.34	.44	.50	.17	.43
15. Distance from center	-.11	-.39	-.17	-.27	-.26	-.27	-.22	-.28
16. Lines of symmetry	-.02	.27	.20	.14	.21	.11	.28	.19
17. Area of figure	.32	.41	.41	.44	.44	.42	.42	.47
18. Area of pattern	-.04	.02	.04	.03	-.01	-.08	.17	.01
19. Ratio of 17 to 18	.29	.28	.21	.30	.30	.38	.12	.32
20. Closed figures within figure	-.04	.10	.17	.08	.11	.06	.15	.10
21. Intersections	-.37	-.28	-.09	-.24	-.30	-.40	-.03	-.29
22. Variance of line density	-.44	.01	.12	-.04	-.14	-.14	-.02	-.10
23. Combination of 10, 13, 14, 17, 19	.64	.48	.16	.40	.52	.55	.27	.50

eight variables were intercorrelated eight times; once for all 256 subjects, and once each for the high HFT group, the low HFT group, males, females, sixth, eighth, and tenth graders. The resulting correlations of the eight variables for the eight groups are given in Table 13.2. The levels of significance of each correlation are given by asterisks. A few comments concerning the results in Table 13.2 are in order. Note that IQ correlated significantly with HFT, TIPT, and CLP, and all three tests also correlated significantly with GPA. The HFT correlated significantly with both the TIPT and the CLP though the correlations were small. As grade increased, the correlation between HFT and TIPT also increased which showed that information processing ability becomes an increasing part of level of field articulation with increasing age.

Analysis of variance. The HFT score; the IQ score; the GPA of English, math, social studies and the total of these three; 10 dependent measures of the TIPT; and nine dependent measures of the CLP were all analyzed using analysis of variance. A 2 x 2 x 3 factorial design was used with all the analyses, which numbered 25. The factors were high or low HFT score, male or female, and sixth, eighth, or tenth grade. In Table 13.3 a summary of the *F* ratios is presented. Table 13.4 shows the means and standard deviations for each factor. Many of the differences between means were significant. The high-low HFT factor was significant in 14 of the 25 analyses. The sex factor was significant six times, and the grade level factor 14 times. Rather than discuss the 25 individual analyses at length, general conclusions which can be drawn from them will be presented in the discussion section.

Discussion

From the results of the experiment the following conclusions seem warranted:

1. There is a significant increase in analytical ability as subjects increase in age from 12 to 16 years. Males and females do not differ in average analytical ability, but proportionately more males than females are high analytically

2. The items of the HFT vary significantly in difficulty. As the relevant lines or relevant area in the figure increases, the hidden figure is easier to locate. As the irrelevant lines, figures, area, or intersections increase, finding the hidden figure is more difficult. The ratios of relevant to irrelevant information correlate well with item difficulty. As the value of these ratios increase, the figure is easier to locate. Combining various measures of relevant information and the ratios provides the best predictor of item difficulty.

3. Young analytical subjects are more sensitive to the amounts of relevant and irrelevant information than are the global subjects. As the analytical subjects grow more mature, their sensitivity to absolute and relative amounts of each type of information decreases. With age, the subjects develop powers of analysis that are independent of the information load. Males and females do not react differentially to any measure of information.

Table 13.2

Correlations of Eight Variables for All Subjects, High and Low HFT Scorers, Males and Females, and Sixth, Eighth, and Tenth Graders

Group	HFT and IQ	HFT and CLP	HFT and TIPT	HFT and ENG	HFT and SS	HFT and MATH	HFT and TOTAL	IQ and CLP	IQ and TIPT	IQ and ENG	IQ and SS	IQ and MATH	IQ and TOTAL	CLP and TIPT
All Ss	.38**	.15*	.24**	.21**	.23**	.22**	.26**	.25**	.30**	.50**	.50**	.44**	.56**	.19**
High	.27**	.07	.21**	.04	.15	.16	.13	.25**	.34**	.43**	.49**	.41**	.51**	.16
Low	.24**	-.09	.07	.10	.13	-.02	.08	.16	.18*	.52**	.47**	.40**	.55**	.16
Males	.38**	.09	.17	.22**	.18*	.25**	.25**	.27**	.22**	.45**	.46**	.47**	.53**	.29**
Females	.43**	.23**	.34**	.25**	.31**	.18*	.30**	.20*	.36**	.53**	.52**	.42**	.58**	.07
Sixth	.34**	.18	.16	.26*	.19	.30**	.30**	.32**a	.15b	.59**	.46**	.63**c	.67**	-.05d
Eighth	.42**	.07	.04b	.35**	.27**	.30**	.34**	.00b	.27**	.66**a	.60**	.54**	.66**	.11b
Tenth	.40**	.17	.35**a	.13	.31**	.08	.21*	.33**a	.44**a	.42**b	.55**	.27**d	.51**	.40**ac

Group	CLP and ENG	CLP and SS	CLP and MATH	CLP and TOTAL	TIPT and ENG	TIPT and SS	TIPT and MATH	TIPT and TOTAL	ENG and SS	ENG and MATH	ENG and TOTAL	SS and MATH	SS and TOTAL	MATH and TOTAL
All Ss	.12	.14*	.12*	.15*	.16**	.20**	.15**	.20**	.70**	.56**	.88**	.55**	.87**	.82**
High	.06	.10	.01	.07	.06	.16	.11	.13	.71**	.53**	.87**	.60**	.90**a	.82**
Low	.12	.14	.18*	.18	.23**	.20*	.14	.23**	.65**	.54**	.88**	.44**	.82**b	.80**
Males	.13	.12	.16	.15	.05	.09	.16	.11	.73**	.63**	.90**	.58**	.88**	.84**
Females	.09	.16	.08	.13	.23**	.29**	.16	.27**	.65**	.50**	.85**	.53**	.87**	.81**
Sixth	.23*a	.18	.20	.24*a	.14	.19	.19	.20	.55**d	.56**	.85**	.52**d	.82**d	.83**
Eighth	-.12b	-.06b	-.06	-.08b	.15	.17	.10	.16	.79**ac	.64**	.90**	.76**c	.94**c	.87**c
Tenth	.22a	.27**a	.20	.28**a	.26*	.33**	.17	.32**	.59**b	.46**	.85**	.34**d	.79**d	.75**b

*p<.05 **p<.01 a,b difference p<.05 c,d difference p<.01

Table 13.3

Summary of the Analysis of Variance F ratios for the 25 Dependent Variables

Dependent Variable	HFT	Sex	Grade	HFT X Sex	HFT X Grade	Sex X Grade	HFT X Sex X Grade
1. HFT Score	429.44**	2.02	5.51**	2.13	-	-	-
2. IQ	25.61**	7.53**	-	-	-	-	1.28
3. English GPA	17.93**	10.10**	14.61**	-	1.72	-	1.65
4. Social Studies GPA	11.20**	2.22	12.09**	-	-	2.62	-
5. Mathematics GPA	10.94**	-	2.81	1.15	-	-	-
6. Total GPA	18.15**	3.09	11.38**	-	1.14	-	-
7. # Right "Yes" Items	3.82	5.83*	5.65**	-	2.16	-	-
8. # Right "No" Items	2.11	-	2.47	-	-	-	-
9. # Right "CT" Items	5.42*	5.01*	-	1.04	2.30	-	-
10. YES Card Errors	4.27*	6.26*	2.89	-	2.10	-	-
11. NO Card Errors	5.45*	3.35	2.05	-	2.49	-	-
12. "CT" Errors on YES	-	-	4.26*	-	-	-	-
13. "CT" Errors on NO	-	-	2.90	1.85	-	-	1.21
14. "Yes" Errors on YES	1.04	-	4.44*	1.07	-	-	3.32*
15. "No" Errors on NO	-	2.73	1.18	-	-	-	-
16. Total Right, TIPT	7.84**	6.66*	3.63*	-	3.33*	-	-
17. Inclusion Error CLP#1	3.09	-	7.36**	1.42	1.30	-	-
18. Inclusion Error CLP#2	3.48	-	6.53**	-	-	1.40	-
19. Total Inc. Errors CLP	4.86*	-	8.76**	-	-	-	-
20. Exclusion Error CLP#1	-	1.18	-	-	1.48	2.69	-
21. Exclusion Error CLP#2	3.93*	-	7.08**	-	1.34	-	1.10
22. Total Exc. Errors CLP	2.80	-	4.42*	-	-	1.14	-
23. # Right CLP #1	1.67	-	4.88**	2.85	2.84	2.10	1.59
24. # Right CLP #2	7.22**	-	-	-	-	-	-
25. Total Right, CLP	8.11**	-	-	-	1.06	1.98	-

** Significant at the .01 level
* Significant at the .05 level

Table 13.4

Means and Standard Deviations by Groups for the Dependent Variables*

	TIPT																CLP								
			GPA				Correct Item Type			Errors Card		Errors CT on		Errors Yes/No on			Errors Inclusion			Errors Exclusion			Correct		
Group	HFT	IQ	ENG	SS	MATH	SUM	Yes No	No	CT	YES	NO	YES	NO	YES	NO	TOTAL RIGHT	#1	#2	SUM	#1	#2	SUM	#1	#2	SUM
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
All Ss																									
X̄	575	10800	240	226	232	698	469	514	429	867	715	307	339	167	155	1412	136	70	206	128	230	358	932	898	1830
sd	260	1103	97	92	94	242	265	221	193							464									303
High																									
X̄	765	11101	259	241	250	750	502	536	452	829	678	307	330	157	151	1490	121	54	175	125	214	339	951	930	1881
sd	177	993	96	96	91	244	273	237	198							503									320
Low																									
X̄	351	10447	217	208	210	635	431	490	403	911	758	308	350	178	160	1324	155	87	242	132	249	381	911	862	1773
sd	132	1126	94	83	93	225	250	199	183							399									271
Males																									
X̄	597	10635	219	216	234	669	436	509	402	907	740	315	326	169	165	1347	141	71	212	135	233	368	919	894	1813
sd	272	1141	102	94	98	257	277	217	191							450									309
Females																									
X̄	553	10984	260	236	230	726	502	519	456	827	690	299	352	165	145	1477	131	69	200	122	228	350	945	902	1847
sd	247	1036	87	89	89	224	263	225	191							471									296
Sixth																									
X̄	508	10739	218	214	214	646	410	476	446	922	742	342	378	200	152	1332	183	105	288	122	178	300	891	914	1805
sd	234	1159	70	65	66	168	250	227	186							409									296
Eighth																									
X̄	565	10789	285	265	249	799	452	511	411	874	747	318	333	161	171	1374	97	66	163	136	252	388	967	882	1849
sd	246	930	103	102	106	282	262	206	191							448									265
Tenth																									
X̄	652	10873	218	202	234	654	545	557	429	807	660	260	306	140	145	1531	127	37	164	129	263	392	942	899	1841
sd	281	1163	100	95	102	238	263	223	199							513									342

*All numbers in the body of the table are 100 times the actual value.

4. Analytical subjects are significantly superior to global subjects in the ability to process information and attain concepts.

5. The analytical subjects show higher school achievement in English, social studies, and mathematics than do the global subjects. The analytical subjects are generally more intelligent. Limited information processing (TIPT) and concept learning each correlate significantly with intelligence and to a lesser extent with achievement.

6. English, social studies, and mathematics are equally useful in predicting success in analytical ability, limited information processing (TIPT), and concept learning.

7. Global subjects show more errors of inclusion, exclusion, and indecision in information processing than do analytical subjects. In concept learning, global subjects also show more overall inclusion errors, and when concepts are difficult, more exclusion errors than the analytical subjects. Female subjects make fewer errors of inclusion, exclusion, and indecision in information processing than do male subjects. As grade level increases, the subjects show an increasing ability to make fewer inclusion errors in both information processing and concept learning.

8. Females are slightly better than males in limited processing information (TIPT), but no differences appear in concept learning. With increasing grade level the analytical subjects increase in the ability to process information. Ability in concept learning increases with age.

9. The HFT shows an adequate level of internal consistency and all the items contribute to the reliability of the instrument. The items are difficult for sixth through tenth graders, but the test discriminates satisfactorily among individuals. The test of information processing shows good internal consistency though some of the items contribute little to the reliability of the instrument. The several dependent measures that the test provides make it a good research tool. The concept learning problems are also very reliable.

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IDENTIFICATION OF ABILITIES IN CONCEPT ATTAINMENT THROUGH FACTOR ANALYSIS

Abstract

Two factor-analytic studies were carried out to clarify cognitive processes in concept learning. In the first study, experiment 14, geometric stimulus material was employed and the concepts to be attained were conjunctive of two or three values. The material was presented simultaneously. In one condition the subjects selected instances from an entire array and in the other condition only the instances needed to attain the concept were presented. Scores from 16 tests, two for each of eight abilities (General Reasoning, Verbal Comprehension, Induction, Deduction, Spatial Scanning, Perceptual Speed, Rote Memory, and Span Memory), and 18 scores from concept-attainment and limited information-processing tasks were obtained from each of 94 female subjects enrolled in educational psychology at the University of Wisconsin. The 34 task and ability variables were intercorrelated, then factored using Alpha factor analysis. The 12 Alpha factors were rotated to an oblique solution according to the Harris-Kaiser criterion. Seven of the eight hypothesized ability factors were identified, the only exception being Perceptual Speed. Five factors associated with the tasks were identified: three concept-attainment and two limited information processing factors. The 12 factors were then correlated. General Reasoning, Induction, and Verbal Comprehension to a lesser extent, correlated positively with the three concept attainment factors. Equally important, Rote Memory, Span Memory, Spatial Scanning, and Deduction did not. It was hypothesized that the first three would be correlated with concept attainment in the selection condition but not in the minimum-instance condition. Limited Information Processing (i.e., inferring whether instances belong to the same concept as the focus based on comparison of the value of positive and negative instances) also exhibited low but positive correlations with concept attainment. As expected, the corelations were higher with concept attainment when only the minimum instances needed to attain the concept were presented than when the entire instance population was presented from which the subject selected instances.

In the second study, experiment 15, the stimulus material, other task conditions, and the ability tests varied from the preceding. Here, six consecutive propositions were presented in written form and each was followed with a written statement of a positive instance of the concept to be attained, a negative instance, or both. After studying the proposition and instances, the subject sorted test instances as belonging or not belonging to the concept. At the end of each of the six consecutive trials, a dependent measure was taken. Scores from 16 tests, two for each of eight abilities (Memory for Semantic Classes, Memory for Semantic Relations, Memory for Semantic Transformations, Induction, Syllogistic Reasoning, Cognition of Semantic Systems, Evaluation of Semantic Relations, and Cognition of Semantic Units), and six scores from different stages (trials) of the concept learning task were obtained from

each of 102 female subjects enrolled in educational psychology at the University of Wisconsin. This total group was subsequently divided into two groups of higher achievers and lower achievers with Ns of 50 and 52. The division was based on the median number of errors on the sixth and last trial.

The derived orthogonal solution was obtained by Kaiser's normal varimax rotation procedures. Six interpreted and one uninterpretable factor were identified. The six interpreted factors were Meaningful Memory, Within Task "Practice," Verbal Comprehension, Early Task "Practice," Reasoning, and Logical Reasoning. Of particular interest were the other abilities associated with the task factors and the differences between higher achievers and lower achievers. The Within-Task factor showed significant loadings on all trials for higher achievers, for trials 3-6 for lower achievers. Memory test scores loaded on the Within-Task factor for the lower achievers but not for the higher achievers; whereas both inductive reasoning and cognizing semantic relations loaded on this factor for the higher achievers but not for the lower achievers. Thus, after the first trial, the higher achievers were already cognizing the relationships among the propositions, instances, and the concept. This did not occur systematically in the loadings until the third trial for the lower achievers. The lower achievers thus apparently had to memorize instances and propositions rather than cognizing relationships and drawing correct inferences concerning class membership. In the Early Task Factor, which was the best indicator of efficient learning, Evaluating Semantic Relations loaded heavily for both groups, suggesting that of importance was not only cognizing the relations among propositions and instances, but also evaluating them on the basis of the defining properties of the concept. Memory for Semantic Relations loaded on the Early Task Factor for the lower achievers but not for the higher achievers; whereas Inductive Reasoning loaded on this factor for the higher but not the lower achievers.

IDENTIFICATION OF ABILITIES IN CONCEPT ATTAINMENT THROUGH FACTOR ANALYSIS[1]

In the scientific study of concept learning, variables have been classified in five categories: (a) stimulus, referring to variables associated with the material in which the concepts are embedded; (b) instructions, referring to information presented to the subjects in oral or written form concerning the task, procedures, and the like; (c) organismic, referring to physical and cognitive characteristics of the subjects; (d) response, referring to the type and number of responses required; and (e) conditions of learning, referring to task variables such as pre-experimental training and feedback. Two factor-analytic studies were undertaken to clarify the relationships of certain organismic variables, cognitive abilities, to concept learning.

Hovland (1952) and Hunt (1962) treated concept learning and information processing as synonymous. In the present experiments, concept learning is seen to be comprised of at least three general aspects, one of which is information processing. These three aspects of concept learning are cognizing the structure of the concept population, formulating and testing hypotheses, and processing information to identify the specific characteristics of the concept. Cognitive abilities are relevant to all aspects of the concept learning task.

Several factor-analytic studies dealing with reasoning abilities have specifically named a concept learning factor. Adkins and Lyerly (1952) extracted a concept formation factor which was described as the "ability to formulate abstract or precise verbal concepts." The three tests identifying the factor were Picture-Group Naming, Word-Group Naming, and Verbal Analogies. Subsequently, Matin and Adkins (1954) reported a second-order factor analysis of the thirteen interpretable factors extracted in the Adkins and Lyerly study. One of the second-order factors was "Precision in Formation and Use of Verbal Concepts," which loaded positively on Concept Formation and Verbal Relations and negatively on Perceptual Speed. Corter (1952) "weakly identified" a factor as concept ability. He stated that the factor ". . . apparently involves the ability to recognize essential similarities, to abstract and generalize, to think inductively"(p. 28).

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[1]The present report is based on Ph.D. theses conducted by Elmer A. Lemke (experiment 14) and Dorothy L. Jones (experiment 15) during the academic years 1964-65 and 1966-67, under the supervision of Chester W. Harris. The report was written by Dorothy Frayer and Herbert J. Klausmeier.

Ability test variables have been related to concept learning in several factor-analytic investigations. Ferguson (1954, 1956) pointed out the relationship between abilities and learning. He defined abilities as ". . . attributes of behavior, which through learning have attained a crude stability or invariance in the adult" (Ferguson, 1956, p. 121). Different abilities result in different amounts of transfer on a given learning task. Also, a given ability may produce different amounts of transfer at different stages of practice on a learning task.

An ability may be conceived of as a combination of an operation or process, a content, and a product (Guilford, 1959). Viewing abilities in this manner permits a finer analysis of learning than is possible with a more global concept of ability.

Two general approaches have been used in the factor-analytic study of abilities and learning. In one approach, the reference frame for the factors is established by analyzing only the ability test scores. The loadings of learning task variables on factors common to the ability tests is derived by an extension of the correlation matrix and factor matrix to include the learning scores. In the second approach, the reference frame for the factors is established by analyzing the ability test and learning scores together. The latter approach has been employed in the present studies.

Stake (1961) administered to seventh graders 12 "short-term" learning tasks which were specially devised to parallel scholastic-type learning situations. Half of the tasks were of the rote-memory type; the other tasks required the discovery of relationships. Word Groups was the only task requiring categorizing behavior; cards bearing words had to be sorted into four categories: white things, household things, common edibles, and living things. Corrective feedback was provided.

A hyperbolic learning curve was fitted to scores taken at successive stages of practice for each person for each task. Two learning curve parameters and the standard error of fit were used to define task performance. A total of 72 variables (learning tasks, ability tests, achievement tests, intelligence tests, race, and course marks) were factor-analyzed. No factors were isolated which differentiated rote learning from relational learning performance. Scores on Word Groups had no appreciable loadings on any common factor.

Allison (1960) also employed the "fitted learning curve" technique to derive learning measures suitable for subsequent task analysis. Thirteen learning tasks, 34 reference tests and three intelligence tests were administered to a group of adults. Included in the groups of learning tasks (hypothesized as representing conceptual, rote, and memory learning) were four concept learning tasks which involved assigning letters as labels to sets of words or figures. Immediate feedback was provided. A verbal conceptual-learning factor and a spatial conceptual-learning factor resulted from the analysis. Through an inter-battery factor analysis a

conceptual process factor was established which was common to the learning measures and reference tests.

Duncanson (1966) reported another investigation of interrelationships between learning measures and ability scores. Nine different tasks, systematically evolved by combining each of three types of material (verbal, numerical, and figural) with each of three types of task (concept formation, paired associates, and rote memory), were administered to sixth grade students. Concept-formation tasks were patterned after the Wisconsin Card Sorting Task, and immediate feedback followed the student's response.

Individualized raw scores obtained over stages of practice for each task were converted by a method developed by Tucker (1960) into a set of learning measures assumed to describe an individual's learning performance. The derived learning measures for all tasks were factor-analyzed along with scores on 15 ability tests, one intelligence test, and six achievement tests. Results indicated that the concept formation task used in the study did not exhibit interrelationships with the abilities measured.

Manley (1965) investigated individual differences common to three different concept attainment tasks and 16 ability tests for a population of ninth grade boys and two subpopulations, concept solvers and nonsolvers. The tasks employed were of three types: nonverbal concepts defined by the physical dimensions of the stimuli (card sort task); nonverbal concepts defined by the "thing" quality of the stimulus (Goldstein's tasks); and verbal concepts (Allison's tasks).

Both learning measures and ability test scores were factor-analyzed together. Three factors loaded on both ability tests and concept attainment tasks. Concept Attainment A was isolated by Allison's tasks and was described as a verbal concept attainment factor. Deductive reasoning tests showed weak loadings on this factor. Concept Attainment B was specific to the card sort tasks for solvers but showed additional substantial loadings on an induction test for the total population and for nonsolvers. Concept Attainment C was primarily defined by the Goldstein tasks. An additional factor which emerged was interpreted as sequence of concept tasks. It was concluded that there are few commonalities existing among tasks employed in the study, that nonsolvers use different abilities in solving concept attainment tasks than solvers, and that relations do exist between certain concept attainment and reference test abilities.

Dunham, Guilford, and Hoepfner (1966) administered to high school students 43 intellectual aptitude tests designed to measure 15 abilities postulated by the structure-of-intellect theory. Of the 15, 11 pertained to classes and four were reference factors involving units and systems. Three concept learning tasks employing three types of content (figural, symbolic, semantic) were also

administered to the students. All three tasks required the student to assign exemplars to one of four concepts.

A factor analysis was carried out on the ability test scores and all 15 hypothesized factors were identified: cognition of figural classes (CFC); cognition of symbolic classes (CSC); cognition of semantic units (CMU); cognition of semantic classes (CMC); cognition of semantic systems (CMS); memory for symbolic classes (MSC); memory for semantic classes (MMC); divergent production of figural classes (DFC); divergent production of symbolic units (DSU); divergent production of symbolic classes (DSC); divergent production of semantic classes (DMC); convergent production of figural classes (NFC); convergent production of symbolic classes (NSC); convergent production of semantic units (NMU); and convergent production of semantic classes (NMC). Three scores were determined for each of the learning tasks: number of correct responses for each learning stage, number of correctly verbalized concepts at the completion of practice on each task, and number of trials needed to reach a predefined criterion. Loadings of these task variables on factors common to the ability tests were derived by an extension procedure. Factorial complexity of task measures was difficult to assess since loadings were not sizable. Although factor loadings on stage score variables were low, changes in factorial structure over practice were reported.

Bunderson (1967) examined the factorial structure of learning measures over six stages of practice within the common factor space defined by 30 ability tests. The 30 ability tests and 26 concept learning problems were administered to a group of university undergraduates. The concept task required identification of a conjunctive concept following successive presentation of a series of geometric stimuli. Factor analysis of the ability tests produced ten interpretable factors: three reasoning abilities, two flexibility factors, three memory abilities, and two visual-speed factors. The relationship of performance at different stages of practice to each of the ten factors was determined by a factor extension procedure. It was found that the abilities transferred differentially at different stages of practice. The data provided empirical support for postulated higher-order processes of problem analysis, search, and organization.

This brief review of factor-analytic studies of concept learning leads to several conclusions. Performance on learning tasks and measured abilities are related. These relationships may change over stages of practice on a learning task, differ for subjects having high and low performance scores, and vary with the type of learning task employed. In addition, there appear to be factors common to learning task scores that are not in common with ability test measures.

Experiment 14: Relationship of Selected Cognitive Abilities to Concept Attainment and Limited Information Processing

Purpose

This investigation is specifically concerned with identifying those factors or abilities that are highly related to concept attainment and information processing. After a review of the hypothesized factors of intellect and tests intended to measure them, eight factors were selected for study based on their presumed relevance or lack of relevance to the concept-attainment and limited information-processing tasks to be employed.

A brief description of these eight factors, based on French, Ekstrom, and Price (1963), and an indication of their presumed relationship to concept attainment will clarify the rationale of the present study.

Rote Memory is defined as the ability to retain bits of unrelated material. When a subject first encounters a large amount of stimulus material of the type used in this study, he may perceive it as being unrelated (although it is actually highly related). To attain a concept wherein information is tested successively, as in the present study, a subject must be able to retain the information. Some type of memory appears to be required for efficient concept attainment.

Span Memory involves the ability to recall perfectly for immediate production a series of items after only one presentation. Although the mode of presentation was simultaneous in the concept-attainment tasks, the subject's identification of instances as exemplars or nonexemplars was sequential in Task 1. The instances' sequential identification by number was seen as a basis for including the Span Memory factor.

Perceptual Speed involves speed in finding figures, making comparisons, and carrying out other very simple tasks involving visual perception. Both concept-attainment tasks and the special information-processing tasks of the present study presumably require the ability to make comparisons of figural material. The subject must discriminate among visual stimuli and make comparisons in order to secure essential information.

General Reasoning (Cognition of Semantic Systems) is the ability to solve a broad range of problems that require production of a generally accepted correct solution, including those of a mathematical nature. Although the stimulus material in the present study is not mathematical, attaining a concept presumably required the ability to compare information and to arrive at a correct solution.

Deduction (Syllogistic Reasoning) involves the ability to reason from stated premises to their necessary conclusions. In the present study, the information-processing tasks might presumably have required

this ability in that propositions of a similar type comprised the items of the limited information-processing task: If the focus card is a member of the group, and the second stimulus card is also, does the third card definitely belong to the group, definitely not belong to the group, or can its membership not be determined?

Induction probably involves several abilities associated with the finding of general concepts that will fit sets of data, the forming and trying out of hypotheses. The concept-attainment tasks presumably involved these abilities directly; to a lesser extent the limited information-processing tasks presumably did also.

Spatial Scanning requires the ability to explore visually a wide or complicated spatial field. Finding one's way through a paper maze is a test of this ability. A planning ability may also be involved. If this ability is related to any task in the present study, it should presumably be concept-attainment Task 1, not the other performance tasks.

Verbal Comprehension (Cognition of Semantic Units) is the ability to understand the English language. The importance of the factor in both the British factor hierarchy and the Thurstone studies suggested its inclusion in the investigation.

The present study, then, was designed to clarify relationships among cognitive abilities, limited information processing, and concept attainment. A factor analysis, to an oblique criterion, of the ability (cognitive variables) and task (limited information-processing and concept-attainment criterion variables) scores provided the model for the study. The matrix of intercorrelations of ability and task factors resulting from the oblique factor rotation provided the desired relationships.

Subjects

The subjects for the study were 94 graduate and undergraduate females from two educational psychology classes. All subjects participated in four sessions of group testing and a fifth individualized concept-attainment session. All subjects were in the age range of 20-35 and had a median age of 21 years.

Experimental Materials

The stimulus materials were patterned after the Wisconsin Card Sorting Task. The concept-attainment display consisted of an ordered arrangement of attributes, by rows, and columns, which formed an 8 x 8 array of 64 cards. On every card six attributes were presented by one of two defining characteristics which were: (a) border number (one or two), (b) border continuity (solid or broken), (c) figure number (one or two), (d) figure size (large or small), (e) figure color (red or green), (f) figure shape (circle or ellipse). These same six attributes were used in constructing slides for the limited information-processing task.

A battery of 16 ability tests from the Reference Kit for Cognitive Factors (French, Ekstrom, and Price, 1963) were used to measure eight factors. Table 14.1 presents the factor, number of items, and reliability coefficient for each test.

Experimental Procedure

Each subject attained a set of two selection concepts and a set of four presented concepts. For the first two concepts, the subject selected instances from a display in which all the stimulus material was presented simultaneously. The concepts to be attained were of two and three relevant attributes, for example, small, red figures; two borders, small, red figures. Subjects were randomly assigned to one of two sequences in order to control for the complexity effect of the concepts. The sequences were: two-attribute concept, three-attribute concept; or three-attribute concept, two-attribute concept.

After attaining the first two selection concepts, each subject attained four concepts from a minimally sufficient set of simultaneously presented information. These four concepts were solved in a sequence with positive and negative instances varying one attribute from the focus card in the first two concepts. In the last two concepts to be attained, negative instances were varied one attribute, but only one positive instance was used to attain the minimally sufficient set of information. The sequence was comprised of concepts of two, three, two, and three relevant attributes.

Task 1, in which subject selected instances from a total display, had these measures of efficiency: time required to attain the concept, an index of manifested information, and total number of cards chosen prior to attaining the concept. Task 2, wherein a minimally sufficient set of information was presented to subject, had time to attain the concept as the index of efficiency. In the information-processing task, scores on each of eight subtests were performance criteria. The index of manifest information in Task 1 was defined as amount of information manifested in the first hypothesis, or statement of the concept, from that potentially obtained. Thus, if five bits were potentially obtained but only three were manifested in the hypothesis, the index was .60. The subjects were asked for a concept after their sixth card choice if one had not been previously offered.

The limited information-processing task was administered in a large group-testing session after the individually administered concept-attainment session. Stimulus materials, or instances of concepts, were presented on 3 x 3 slides. Each slide thus comprised an item and was subsequently scored as correct or incorrect.

That part of the experiment dealing with limited information-processing consisted of the subject responding to 60 items. The first 30 were of the type in which one card, either an exemplar or a nonexemplar, was presented in addition to the exemplar focus

Table 14.1

Reliability Estimates of Identification Variables for Eight Hypothesized Factors

Factor	Test	No. of Items	Procedure	r_{tt}
Rote Memory	Object-Number	15	Split-half	.68
	First and Last Names	30	Split-half	.77
Verbal Comprehension (Cognition of Semantic Units)	Vocabulary	36	Split-half	.86
	Advanced Vocabulary	36	Split-half	.81
Deduction (Syllogistic Reasoning)	Logical Reasoning	40	Split-half	.72
	Nonsense Syllogisms	30	K. R. 20	.88
Span Memory	Auditory Number Span	24	K. R. 20	.62
	Auditory Letter Span	24	K. R. 20	.76
General Reasoning (Cognition of Semantic Systems)	Ship Destination	57	Split-half	.93
	Necessary Arithmetic Operations	15	Split-half	.74
Perceptual Speed	Finding A's	25		a
	Number Comparison	24		a
Induction	Locations	28	Split-half	.82
	Letter Sets	30	Split-half	.64
Spatial	Map Planning	20		a
	Maze Tracing Speed Test	24		a

[a] Traditional computational techniques not appropriate.

card. The task was to specify the inclusion, exclusion, or indeterminateness of a third card to membership in a group of cards exemplifying the concept. The problems in which exemplars were presented numbered 15 and those presenting nonexemplars also 15. Of these 15 exemplar items, ten cards whose membership was to be determined were definitely exemplars of the same concepts as the focus card. The membership of the remaining five test cards could not be determined. In the 15 problems presenting a focus card and a nonexemplar, ten test cards were definitely not exemplars and five were again not determinable. Thus these 30 items could be scored on the basis of test membership exemplar, nonexemplar, and indeterminate.

The second set of 30 items was constructed, using the same focus card and test cards as in the first set. The information presented in addition to the exemplar focus card consisted of two cards instead of one as was the case with the first set. One of the two cards for each problem was an additional exemplar; the other was the same in kind as its counterpart in the first 30 items. The answers to the 30 items of the second set were identical to those in the first set. Thus, the two sets were the same except that the information presented about the test card in the second subtest included the additional complexity of one card.

Table 14.2 gives the design of the arrangement of exemplar and/or nonexemplar instances and number of cards or items per test. As shown in Table 14.2, this information-processing task resulted in eight subscores of information processing based on the type of information contained in the stimulus material.

Table 14.2

Summary Description of Eight Information-Processing Subtests

Subtest	First card	Second card	Decision card	No. of cards
1	yes	--	Inclusion	10
2	yes	--	Indefinite	5
3	no	--	Exclusion	10
4	no	--	Indefinite	5
5	yes	yes	Inclusion	10
6	yes	yes	Indefinite	5
7	yes	no	Exclusion	10
8	yes	no	Indefinite	5

Results

A correlation matrix was obtained for the 34 ability and test variables.[2] Two scale-free models, Incomplete Image analysis (Harris, 1962), and Alpha Factor analysis (Kaiser and Caffrey, 1965) which rescale the reduced correlation matrix in the metric of the unique and common parts, respectively, were employed as data reduction models. Only the Alpha model is reported in this discussion.

A Normal Varimax rotation (Kaiser, 1958) of the Incomplete Image factors yielded 23 factors, eight of which were uninterpretable. The same orthogonal criterion applied to the Alpha factors yielded a derived matrix of 12 factors, all of which were interpretable. The 12 Alpha factors, when rotated to the Normal Varimax criterion, were found to include the following factors (Roman numerals in Table 14.3) identified by the experimental tests of cognitive abilities: (I) Verbal Comprehension, (IV) Rote Memory, (VI) Span Memory, (VII) Spatial Scanning, (X) Deduction, (XI) General Reasoning, and (XII) Induction. The Perceptual Speed factor was not identified. Thus seven of the eight ability factors which the 16 experimental tests were supposed to measure were in fact identified.

Five factors identified by the loadings of the task variables--three concept-attainment and two information-processing factors--were called (Table 14.3): (II) Information Processing (Inclusion-Exclusion), (III) Selection (Concept 2), (V) Presented Concept, (VIII) Selection (Concept 1), (IX) Information Processing (Indeterminate).

To observe ability-task relationships, the Alpha factor matrix was rotated to an oblique solution using the Harris-Kaiser (1964) criterion. Since some variables were of complexity greater than one, the A'A proportional to L case was used. Table 14.3 represents the 34 x 12 oblique factor matrix.

Italic loadings of Table 14.3 provided the rationale for oblique factor descriptions. Only the Induction factor, educed from the Letter Sets and Locations tests, presented some difficulty in identification. Thurstone's (1940) isolation of this factor from the Letter Grouping test facilitated the factor identification. (See also Goodman, 1943; Kettner, Guilford, and Christensen, 1959; Thurstone and Thurstone, 1941). The Spatial Scanning factor, previously isolated but unidentified by Thurstone and Thurstone, (1941)

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[2]The original correlation matrix appears in Lemke, E. A., The relationship of selected abilities to some laboratory concept attainment and information processing tasks. Unpublished doctoral dissertation, University of Wisconsin, 1965.

Table 14.3

Rotated Factors of $H^{-1}(R-S^2)H^{-1}$
(Oblique Criterion)

Test	V. I	I.P. II	Sel. III	R.M. IV	Pres. VI	S.M. VI	S.S. VII	Sel. VIII	I.P. IX	D. X	G.R. XI	I. XII
1. Object-Number	−335	054	−062	*682*	162	064	066	−029	189	079	−052	062
2. First and Last Names	241	072	029	*594*	−163	−007	−101	−039	024	−006	−019	002
3. Vocabulary	*758*	035	049	038	−026	072	−009	150	−038	056	−096	021
4. Advanced Vocabulary	*900*	−112	010	000	−013	−001	037	−080	005	051	021	−142
5. Logical Reasoning	074	−077	043	042	061	−129	−013	−043	077	*754*	056	063
6. Nonsense Syllogisms	035	255	−431	−104	066	123	−122	158	−082	*338*	*634*	−138
7. Auditory Number Span	−026	−049	055	010	−009	*839*	068	−094	025	−039	113	−024
8. Auditory Letter Span	081	−061	012	072	019	*750*	084	052	−016	−106	001	034
9. Ship Destination	−066	017	022	−212	−030	015	*213*	−143	072	−068	*711*	094
10. Necessary Arithmetic Operations	065	−020	171	018	−127	025	−011	−298	166	137	*566*	−213
11. Finding A's	055	−112	−116	303	022	110	009	040	−307	−034	438	093
12. Number Comparisons Test	178	−040	072	221	031	−305	*543*	−112	−304	−054	074	013
13. Locations Test	−247	060	097	−060	−043	057	−071	172	−192	139	*627*	*204*
14. Letter Sets	−073	−034	038	074	037	019	−019	−083	−010	023	−027	*809*
15. Map Planning	016	080	093	−042	093	178	*698*	016	118	−020	−039	−075
16. Maze Tracing Speed Test	005	−117	−209	−054	−186	−085	*484*	250	−050	027	151	356
17. Selection 1, Time-to-Criterion	045	−099	−025	−035	314	−118	117	*651*	147	−110	253	−170
18. Selection 2, Time-to-Criterion	133	136	*893*	−059	268	180	073	189	−099	025	−030	−021
19. Selection 1, Manifest Index	−130	−155	414	006	−014	−074	−082	*215*	114	−072	159	012
20. Selection 2, Manifest Index	−106	−109	*499*	015	−349	−155	064	006	068	035	292	−066
21. Selection 1, Cards-to-Criterion	007	030	−050	038	−152	014	061	*921*	056	025	−150	−011
22. Selection 2, Cards-to-Criterion	134	351	*478*	−085	−168	322	−061	281	−179	258	−275	175
23. Presented Concept 1	238	034	256	−042	*291*	−198	−102	169	−165	−032	−006	200
24. Presented Concept 2	098	−020	118	033	*483*	−140	138	013	−016	009	162	−030
25. Presented Concept 3	092	019	−125	037	*373*	057	−104	138	−163	−075	357	−117
26. Presented Concept 4	−125	009	069	−034	*712*	013	044	−141	117	102	−154	073
27. Information Processing, Yes—Inclusive	117	*592*	−001	144	−139	−088	−008	040	−068	−068	163	061
28. Information Processing, Yes—Indeterminate	078	112	−121	−096	113	−005	−054	014	*437*	028	−061	376
29. Information Processing, No—No Exclusive	−010	*755*	−101	−035	041	−050	082	−066	048	−176	037	−076
30. Information Processing, No—Indeterminate	112	227	038	−161	−026	−028	−213	−120	191	−328	413	223
31. Information Processing, Yes, Yes—Inclusive	−026	176	072	176	−150	−108	151	128	*512*	−017	189	−191
32. Information Processing, Yes, Yes—Indeterminate	−027	−111	−022	173	095	059	049	062	*654*	012	−007	016
33. Information Processing, Yes, No—Indeterminate	198	−132	132	097	077	017	−305	116	*311*	−110	190	080
34. Information Processing, Yes, No—Exclusive	−182	*796*	110	063	107	−028	018	021	−004	037	−111	−040

and suggested by French et al. (1963) as representing a "planning" function, is also of interest. The strong involvement of this factor with tests from the reasoning domain suggests that there is, in fact, a strong convergent involvement in this type of activity.

The L matrix, the matrix of factor intercorrelations for the 12 task and ability factors, is presented in Table 14.4. Of 21 correlations among seven ability factors (Table 14.4), seven were positive and ranged between .238 and .569; Verbal Comprehension, General Reasoning, and Induction are involved in these seven correlations. Of 10 correlations among three concept-attainment and two information-processing tasks, five were positive and ranged between .213 and .431; the factor Information Processing-Indeterminate was involved in three of five positive correlations. Thus correlations among variables within each of two sets of variables were of about the same magnitude, and the proportion of the total was about the same.

Of 35 correlations between the set of seven ability variables and the set of five task variables, 12 were positive and ranged from .220 to .461. Of these 12 correlations, 10 involved General Reasoning and Induction; the other two, Verbal Comprehension. General Reasoning correlated positively with all five of the task factors, the range being from .363 to .461. Induction also correlated with all five task factors, the range of r's being .229 to .353. Thus General Reasoning, Induction, and, to a lesser extent, Verbal Comprehension correlated substantially and consistently with concept attainment and information processing; the other four abilities--Rote Memory, Span Memory, Spatial Scanning, and Deduction--did not. Further, Information Processing-Indeterminate was the information-processing factor that correlated most consistently with other task factors and the cognitive factors, six of 11 r's ranging between .213 and .431. Presented Concept was the concept-attainment factor to correlate most consistently with task and cognitive ability factors, five of 11 r's ranging between .213 and .461.

Discussion

Low positive correlations were found between a set of cognitive abilities, a set of concept-attainment factors, and a set of information-processing factors. However, several abilities--Verbal Comprehension, General Reasoning, and Induction--correlated consistently with the concept-attainment and information-processing factors. Further, limited information processing correlated positively but lower than expected with concept attainment.

The identification of three relatively distinct concept-attainment factors and two information-processing factors with only a few correlations of modest size among these factors was not anticipated. Consider the three concept-attainment factors. Two of these--Selection Concept I and Selection Concept II--resulted from measure of subjects' attaining two concepts in sequence, under identical experimental conditions;

Table 14.4

Matrix of Intercorrelations of 12 Alpha Factors

	Factor description	I	I	III	IV	V	VI	VII	VIII	IX	X	XI	XII
1.	Verbal Comprehension	1.000	073	164	092	220	016	-002	198	317	289	425	350
2.	Information Processing, Inclusion-Exclusion		1.000	111	141	334	172	144	171	431	085	397	259
3.	Selection I			1.000	105	058	098	060	415	157	116	366	353
4.	Rote Memory				1.000	033	038	194	-011	089	-020	165	200
5.	Presented Concept					1.000	168	106	166	213	145	461	338
6.	Span Memory						1.000	047	116	173	095	128	057
7.	Spatial Scanning							1.000	124	025	089	305	249
8.	Selection II								1.000	278	167	363	229
9.	Information Processing, Indeterminate									1.000	579	411	313
10.	Deduction										1.000	238	127
11.	General Reasoning											1.000	579
12.	Induction												1.000

Note: All decimal points eliminated for off-diagonal elements.

that is, in one sitting with identical instructions, materials, etc. Why did two separate factors result? Subjects first attained a two-attribute and then a three-attribute concept or first a three-attribute and then a two-attribute concept. They were not informed of this attribute change which affected the difficulty level of the concept. Apparently the change in the number of attributes and the ordinal position affected performance in such a manner as to result in separate factors.

The third factor, Presented Concept, resulted from a very different experimental situation. Here the task was for subjects to attain four concepts of two and three attributes in sequence; however, only the minimum number of instances necessary to attain the concept was presented. Thus, attaining the concept under these conditions was distinctly different from that in which a large array was presented simultaneously and subjects selected cards successively.

Limited information processing as defined by eight subtests also yielded two factors, one being based on items of the type where the test instance definitely was or was not a member of the concept, the other being based on items where insufficient information was presented to determine inclusion in the concept. Identification of the two factors suggests that limited information processing is not a unitary ability, much the same as concept attainment is not. Further, limited information processing as defined in this study is only modestly related to concept attainment, more closely, as expected to the Presented Concept.

Experiment 15: Relationships between Concept Learning and Selected Ability Test Variables

Purpose

For this investigation a new type of laboratory concept learning task was devised which would parallel a type of concept learning prevalent in the school situation, i.e., the formal acquisition of second-level concepts. By "second-level concepts" is meant concepts which have other concepts as their denotation as constrasted with first-level concepts which have objects as referents. The task consisted of successively presenting the subject with six postulates, and positive or negative instances of the concept. Each postulate defined some aspect of a particular second-level concept. After reading each postulate and studying the instances, the subject classified fifty sentences as exemplars or nonexemplars of the concept.

Factor analysis was utilized to isolate and identify intellectual abilities associated with successful performance on the learning task. Separate factor analyses were carried on scores for subjects achieving above the median on terminal performance and on scores for subjects below the median. The factorial structure of the laboratory task was compared over successive trials.

Guilford's structure-of-intellect (SI) model provided the theoretical framework for selecting ability tests. Although the SI model dominated factor selection, reference tests were drawn from both the Guilford Laboratory and the Kit of Reference Tests for Cognitive Factors, Educational Testing Service. The final choice was determined by the findings of previous studies and consideration of the nature of the learning task. A brief description of the factors follows:

Memory for Semantic Classes (MMC) is described as ". . . the ability to maintain in storage ideas of common attributes whereby two or more items of information are assigned to the same group or class (Brown, Guilford, and Hoepfner, 1966, p. 9)." In the learning task used in this study, a common attribute of the concept being learned was given to the subject at the beginning of each phase by means of a postulate. Since the postulates were unavailable to the subject while sorting cards into exemplars and nonexemplars of the concept, the common attributes would have to be remembered. This behavior appeared analogous to that required in the tests purporting to represent this factor classification.

Memory for Semantic Relations (MMR) is ". . . the ability to remember meaningful connections between related verbal elements (Brown et al. 1966, p. 9)." During the early phases of the learning task the subject, being forced to make a decision with insufficient information, might revert to recalling exemplars presented in connection with the postulates and also to recalling sentences already sorted. The manner in which a particular sentence is sorted would depend on recall of the connection between verbal elements in previous exemplars.

Memory for Semantic Transformations (MMT) is ". . . the ability to remember redefinitions or other changes in meaning (Brown et al. 1966, p. 10)." In the learning task, discriminating between different meanings implied by the same word used in different contexts was considered necessary for successful performance. For example, a shift in the meaning of the word feel is exemplified by the following three stimulus sentences: "I feel sick," "I feel the baby is crying," and "I can feel the rope shredding."

Induction (I) is described in the following manner in the Manual for Kit of Reference Tests for Cognitive Factors, Educational Testing Service: "Associated abilities involved in the finding of general concepts that will fit sets of data, the forming and trying of hypotheses (French, Ekstrom, and Price, 1963, p. 19)." The presentation of postulates in the learning task was considered analogous to the information given to provide a pattern or rule in the reference tests. The subject was required to apply the rule by identifying exemplars.

Syllogistic Reasoning (RS) is referred to in the Manual for Kit of Reference Tests for Cognitive Factors as the ". . . ability to reason from stated premises to their necessary conclusions . . .

the factor originally called 'Deduction' by Thurstone . . . Guilford has called it 'Logical Evaluation,' the evaluation of semantic relations (French et al. 1963, p. 37)." This factor was included since the subject's success in sorting the stimulus cards at any one phase might depend on his ability to make valid judgments based on the given assumptions (the postulates).

Cognition of Semantic Systems (CMS) is the factor usually called "general reasoning" and is described as ". . . the ability to comprehend relatively complex ideas (Guilford and Hoepfner, 1966, p. 6)." In one of the reference tests for this factor, Ship Destination, successive groups of test items were graduated in complexity by increasing the number of rules required for correct solution. The learning task was thought to reflect the same type of graduated complexity with respect to rule application.

Evaluation of Semantic Relations (EMR) is described as ". . . the ability to make choices among semantic relationships on the basis of similarity of meanings (Guilford and Hoepfner, 1966, p. 12)." In the learning task, the subject was continually forced to evaluate whether the stimulus sentences did or did not meet certain standards or goals. More specifically, during the early sorting phases the subject was required to evaluate relations between words and ideas.

Cognition of Semantic Units (CMU) is defined as ". . . the ability to comprehend the meanings of words (Guilford and Hoepfner, 1966, p. 5)." This is the factor called "verbal comprehension" in most factor-analytic studies. It is hypothesized that this factor will not load substantially on any of the six sorting phases of the learning task.

The present study, then, was designed to clarify relationships among cognitive abilities and scores on a specially-devised concept learning task, at different stages of the task, for achievers and nonachievers. The multivariate models employed in analyzing the learning and ability measures were Alpha factor analysis and a factor-analytic technique producing factors comparable to an incomplete image analysis. All factor matrices were orthogonally rotated by the normal varimax method.

Subjects

Subjects were female upper-division or first-year graduate students enrolled in educational psychology courses at the University of Wisconsin. Of 112 who participated in the learning task, 102 completed the battery of reference tests. These 102 subjects were used in the factor analysis. The mean age of the subjects was 21.1 years.

Experimental Materials

The concept of "perceptual situation" was selected for the learning task. The defining characteristics of this concept were presented as postulates, these being a condensed version of those

given by C. D. Broad (1960). The first five postulates each asserted new information about the concept; the last was for review purposes only. The words "perceptual situation" were never used; the concept was denoted as "the situation" in all postulates. The task was composed of six stages. Each stage was defined by two activities: (1) subject received a new postulate and examples or nonexamples of each; (2) subject sorted a deck of 50 sentence cards.

A short paraphrase of each of the postulates is as follows:

1. The situation requires sensation.
   Example: "I am aware of a red flash."

2. The situation involves an objective element that may be real or hallucinatory.
   Examples: "I hear a bell." "I see a pink elephant."

3. The objective element is physical rather than psychical.
   Example: "I see the dragon."
   Nonexample: "I notice that I am acting spitefully."

4. The situation is intuitive rather than discursive, or involuntary rather than voluntary.
   Example: "I am hearing a bell."
   Nonexample: "I am thinking of a bell."

5. The situation reveals the object as it is rather than as it was.
   Nonexample: "I remember the tie you wore yesterday."

6. The situation requires the involuntary sensation of a physical objective element as it is.

Fifty sentences describing the situations were typed on cards; 17 of these sentences were examples of a perceptual situation and the remaining 33 violated one or more of the postulates. Some examples of the sentences are:

1. I see a pink elephant.
2. I can see the man as a little boy.
3. I can see clearly.
4. I hear the baby crying.
5. I heard about the baby crying.
6. I am aware of the baby crying.
7. I feel the baby is crying.
8. I am aware of my hearing the bell.

Sixteen ability tests were chosen from both the Guilford Laboratory and the Kit of Reference Tests for Cognitive Factors, Educational Testing Service. Table 15.1 presents the factor represented and the reliability coefficient for each test.

Table 15.1

Reliability Estimates of Identification Variables for Eight Hypothesized Factors (N = 102)

Factor	Test	Procedures	r_{tt}
Memory for Semantic Classes (MMC)	Picture Class Memory	Parallel-halves	.59
	Classified Information	Parallel-halves	.83
Memory for Semantic Relations (MMR)	Remembered Relations	Parallel-halves	.70
	Recalled Analogies	Parallel-halves	.51
Memory for Semantic Transformations (MMT)	Double Meanings	Parallel-halves	.78
	Homonyms	Parallel-halves	.71
Induction (I)	*Letter Sets	Parallel-halves	.56
	*Locations	Parallel-halves	.60
Syllogistic Reasoning (RS)--(Deduction)	*Nonsense Syllogisms	Parallel-halves	.64
	*Logical Reasoning	Lower bound estimate obtained from communalities	.40
Cognition of Semantic Systems (CMS)--(General Reasoning)	*Necessary Arithmetic Operations	Parallel-halves	.64
	*Ship Destination	K.R. 21	.56
Cognition of Semantic Units (CMU) (Verbal Comprehension)	*Advanced Vocabulary V-4	Parallel-halves	.70
	*Advanced Vocabulary V-5	Parallel-halves	.78
Evaluation of Semantic Relations (CMR)	Verbal Analogies III	Parallel-halves	.33
	Best Trend Name	Parallel-halves	.54

*Reference tests which were also used in experiment 14.

Experimental Procedure

The subjects were instructed to read the first postulate, and to sort the 50 sentences into two piles, examples and non-examples. After the first sort the subjects read the second postulate and again sorted the 50 sentences. Subjects made six consecutive sorts, each time sorting the cards after they had read an additional postulate.

A pilot study was conducted to evaluate the effects of variations in feedback and postulate availability at the six stages of the concept learning task. Subjects for the pilot study were 32 college students randomly drawn from an educational psychology class. Each subject performed the learning task under one of four conditions: postulate available during sorting, feedback given for each card sorted (P_+F_+); postulate not available during sorting, feedback given for each card sorted (P_-F_+); postulate available, feedback not given (P_+F_-); and postulate not available, feedback not given (P_-F_-).

The results of this pilot study indicated that feedback for each sentence had a definite facilitating effect on accuracy of categorization. The availability of the postulate, however, did not aid concept learning, but seemed to hinder it slightly. It was decided that the learning task using the cell P_-F_- would be of appropriate difficulty for a factor-analytic study of concept learning as a function of stage of learning. Therefore, subjects in the main study were administered the concept learning task in the P_-F_- condition.

The 16 ability tests were given to groups of subjects during an afternoon testing session. The 16 tests and the six card sorts provided 22 measures which were analyzed by factor analysis.

Results

The dependent variables were the total scores on each of the 16 ability tests, and the errors on each of the six successive card sorts. Correlation matrices of these 22 scores were obtained for two subgroups, symbolized and defined as:

$G_{E<12}$: (Achievers), the set of all subjects achieving a total error score less than 12 at the sixth card-sorting stage. (N = 50)

$G_{E\geq 12}$: (Nonachievers), the set of all subjects whose total error score at the sixth card-sort was greater than or equal to 12. (N = 52)[3]

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[3]The original correlation matrices appear in Jones, D. L., Relationship between concept learning and selected ability test variables for an adult population. Unpublished doctoral dissertation, University of Wisconsin, 1967.

Alpha factor analyses (Kaiser and Caffrey, 1965) are reported for each subgroup. The derived orthogonal solutions were both obtained by Kaiser's (1958) normal varimax rotation procedure. Seven Alpha factors were extracted and rotated in each subgroup analysis.

Table 15.2 presents the means and standard deviations of task and test variables for the two subgroups. The rotated factor matrices for the two subgroups are shown in Table 15.3 and 15.4. Note that scores on task variables are total number of errors; scores on ability tests are the number of correct responses. It therefore follows that a positive relationship between a task variable and an ability test is expressed by a negative correlation coefficient.

The subgroup analyses resulted in seven Alpha factors, six of which were interpretable. These factors were:

Meaningful-Memory. Three factors, Alpha I ($G_{E<12}$), Alpha II ($GE\geq12$), and Alpha VII ($G_{E\geq12}$) were interpreted as meaningful-memory factors.

Achievers: All memory tests except Recalled Analogies loaded on Alpha I ($G_{E<12}$). Two reasoning tests, Letter Sets and Ship Destination also correlated substantially with the factor. The first card-sorting stage was negatively related to this factor.

Nonachievers: Alpha VII ($GE\geq12$) was identified by Double Meanings and Remembered Relations. No attempt was made to assign SI model interpretations to this factor, since the recommended correlative tests for MMR and MMT appeared on Alpha II ($GE\geq12$). Alpha II ($GE\geq12$) exhibited highest loadings on three memory tests and three reasoning tests. It appeared that Ship Destination, which had almost 50 percent of its variance accounted for by this factor, measured a memory rather than a reasoning ability for nonachievers.

Within-Task "Practice." This factor was one of the two task factors which appeared in each subgroup analysis.

Achievers: The ability represented by the factor Alpha II ($G_{E<12}$) was apparently used when sorting cards as early as the first stage. Significant loadings on this factor were observed for Induction and CMS reference tests.

Nonachievers: The factor, Alpha I ($GE\geq12$), did not appear for nonachievers until the third stage of the learning task. Picture Class Memory and Recalled Analogies were significantly related to this factor. The loadings of memory tests on this factor for nonachievers as compared with reasoning tests for achievers was considered one of the major findings of the investigation.

Table 15.2

Comparison of the Means and Standard Deviations of Task and Test Variables for the Two Subgroups

Variable Name and Number	Mean $G_{E<12}$	Mean $G_{E>12}$	Standard Deviation $G_{E<12}$	Standard Deviation $G_{E>12}$
1. Task: Sort 1	19.2	23.6	6.54	6.59
2. Task: Sort 2	13.6	19.8	5.96	6.75
3. Task: Sort 3	9.78	14.7	4.40	5.53
4. Task: Sort 4	9.84	17.6	5.95	6.53
5. Task: Sort 5	10.6	20.8	6.24	7.44
6. Task: Sort 6	7.2	16.9	2.50	4.11
7. Picture Class Memory	36.1	33.6	4.79	6.80
8. Classified Information	54.0	54.1	7.34	7.91
9. Remembered Relations	22.8	21.5	6.23	5.63
10. Recalled Analogies	20.1	18.6	4.83	5.13
11. Double Meanings	25.5	24.1	8.56	7.99
12. Homonyms	12.3	11.0	3.55	4.19
13. Letter Sets	23.4	22.1	2.86	3.29
14. Locations	11.6	10.1	3.51	3.53
15. Nonsense Syllogisms	18.8	17.5	4.43	4.10
16. Logical Reasoning	17.0	16.4	2.16	1.91
17. Necessary Arithmetic Operations	21.3	19.4	3.14	3.97
18. Ship Destination	14.7	12.7	2.99	3.38
19. Advanced Vocabulary V-4	23.5	21.4	4.89	4.20
20. Advanced Vocabulary V-5	22.0	19.8	6.07	5.30
21. Verbal Analogies III	13.6	12.6	2.13	2.43
22. Best Trend Name	16.5	15.6	1.94	2.08

Table 15.3

Alpha Factor Analysis, Rotated Factor Matrix
Subgroup $G_{E<12}$ (N = 50)

Variable Name and Number	I	II	III	IV	V	VI	VII	h^2
1. Task: Sort 1	32	41	25	27	-12	02	-09	42
2. Task: Sort 2	07	40	25	78	-07	-07	-23	90
3. Task: Sort 3	06	60	03	41	-07	-20	-16	60
4. Task: Sort 4	-09	85	-11	-01	-15	-01	00	76
5. Task: Sort 5	09	89	06	00	02	-09	-05	82
6. Task: Sort 6	00	45	22	-02	-20	-01	-32	40
7. Picture Class Memory	67	-01	-07	07	13	05	-02	48
8. Classified Information	58	16	04	-13	-04	-01	14	41
9. Remembered Relations	61	-07	-06	-02	35	-02	06	51
10. Recalled Analogies	25	-03	15	-25	43	-04	04	34
11. Double Meanings	72	11	14	04	18	07	-05	59
12. Homonyms	50	-27	28	-04	-10	11	24	48
13. Letter Sets	31	-09	-04	-32	20	15	45	48
14. Locations	19	-33	06	-13	18	65	02	62
15. Nonsense Syllogisms	14	-03	42	-08	53	04	26	56
16. Logical Reasoning	06	-13	13	-16	03	-03	82	73
17. Nec. Arith. Operations	19	-29	-11	-08	69	01	01	62
18. Ship Destination	41	-34	-00	-30	21	01	04	43
19. Adv. Vocabulary V-4	07	06	92	04	-11	-14	01	88
20. Adv. Vocabulary V-5	-00	05	79	-03	18	-07	04	66
21. Verbal Analogies III	01	-05	21	-14	11	-53	-02	36
22. Best Trend Name	08	11	19	-51	14	-17	09	37

NOTE: Decimal points omitted

	I	II	III	IV	V	VI	VII
Variance	2.50	2.89	2.07	1.46	1.41	.86	1.24
Percent of Total Variance	11.34	13.12	9.42	6.63	6.41	3.91	5.63
Percent of Common Variance	20.08	23.24	16.68	11.74	11.36	6.93	9.97
Common Variance =	12.42						

Table 15.4

Alpha Factor Analysis, Rotated Factor Matrix

$\text{Subgroup}_{\underline{E\geq 12}}$ (N = 52)

Variable Name and Number	I	II	III	IV	V	VI	VII	h^2
1. Task: Sort 1	26	-02	-14	-06	67	01	02	54
2. Task: Sort 2	15	-07	-06	00	69	02	-10	52
3. Task: Sort 3	50	11	06	-17	45	12	-24	56
4. Task: Sort 4	77	-10	04	-02	24	-23	-07	73
5. Task: Sort 5	68	-14	-04	02	21	-16	06	55
6. Task: Sort 6	64	-15	-08	-27	15	20	-22	62
7. Picture Class Memory	-35	61	13	02	-02	12	29	62
8. Classified Information	-11	37	07	-18	-20	06	31	32
9. Remembered Relations	-25	41	12	00	-34	-28	42	61
10. Recalled Analogies	-34	31	22	48	06	23	39	70
11. Double Meanings	-07	15	05	00	-10	11	81	71
12. Homonyms	-11	74	-01	08	-06	05	26	64
13. Letter Sets	01	45	-18	52	07	11	-01	53
14. Locations	08	57	-14	27	-02	21	14	49
15. Nonsense Syllogisms	-10	12	11	13	06	73	06	60
16. Logical Reasoning	-11	06	02	63	-11	07	-06	44
17. Nec. Arith. Operations	-06	35	02	32	-37	27	24	50
18. Ship Destination	-08	69	16	16	-15	-01	-21	59
19. Adv. Vocabulary V-4	-05	03	92	-11	-14	-03	12	90
20. Adv. Vocabulary V-5	01	04	74	07	-11	16	-00	59
21. Verbal Analogies III	-14	18	09	08	-42	47	08	46
22. Best Trend Name	-12	30	21	00	-39	12	04	32

NOTE: Decimal points omitted

	I	II	III	IV	V	VI	VII
Variance	2.21	2.68	1.65	1.30	1.97	1.23	1.51
Percent of Total Variance	10.03	12.19	7.52	5.89	8.94	5.58	6.84
Percent of Common Variance	17.60	21.39	13.19	10.33	15.69	9.79	12.01

Common Variance = 12.54

Verbal Comprehension (CMU). This factor, Alpha III ($G_{E<12}$) and Alpha III ($G_{E\geq 12}$), was identified in both subgroup analyses by Advanced Vocabulary V-4 and Advanced Vocabulary V-5. In addition, Nonsense Syllogisms showed a significant loading on this factor for achievers.

Early Task "Practice." Both subgroup analyses isolated a factor which loaded on the early stages of the learning task.

Achievers: The factor, Alpha III ($G_{E<12}$), showed high loadings on stages two and three of the learning task. In addition, reference tests for CMS, EMR, and Induction showed significant loadings on the factor.

Nonachievers: The factor, Alpha V ($G_{E\geq 12}$), had significant loadings on the first three stages of the learning task. Substantial loadings also occurred on CMS and EMR tests as in the achiever analysis. No significant loadings occurred on Induction tests, however. Instead, a high loading occurred on an MMR test.

Reasoning. The only observable link between Alpha V ($G_{E<12}$) and Alpha VI ($G_{E\geq 12}$) was the substantial contribution of Nonsense Syllogisms (RS) to factor variances.

Achievers: Alpha V ($G_{E<12}$) was interpreted as Guilford's CMS. Necessary Arithmetic Operations exhibited its highest loading on the factor. MMR tests also showed significant relationships to this factor.

Nonachievers: Alpha VI ($G_{E\geq 12}$) showed significant loadings only on Nonsense Syllogisms and Verbal Analogies III (EMR). The fact that Nonsense Syllogisms was the only test on which this factor loaded for both achievers and nonachievers suggests that the test measures different constructs for the two subgroups.

Logical Reasoning. The primary identifiers of this factor, Alpha VII ($G_{E<12}$) and Alpha IV ($G_{E\geq 12}$), were the Logical Reasoning (RS) and Letter Sets (I) tests. Secondary loadings on the sixth card-sorting stage permits the conclusion that this factor is related to successful performance on the learning task.

Discussion

The Early Task factor exhibited significant loadings on EMR ability for both subgroups, suggesting that an important process was evaluating relations among the instances on the basis of the defining properties of the concept. An additional loading of the factor on an MMR test for nonachievers and on an induction test for achievers indicates that memory may play a more important role in this process for nonachievers than achievers.

The Within-Task factor showed significant loadings on all trials for achievers, for trials 3-6 for nonachievers. This factor was related to induction and CMS tests for achievers; MMC and MMR tests for nonachievers. Thus, on the first trial, the achievers were already cognizing the relationships among the propositions, instances, and the concept. This did not occur systematically until the third trial for nonachievers. The nonachievers apparently had to memorize propositions and instances rather than cognizing relationships and drawing correct inferences concerning class membership.

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EXPLORATORY STUDIES OF RELATIONSHIPS AMONG VARIABLES[1]

Introduction

The four experiments contained in this section of the report may be regarded as exploratory studies of relationships among variables which are thought to exert a powerful influence on concept attainment behavior. The studies were conducted at various points during the course of the project and each combines two or more independent variables. In several of the studies, at least one of the independent variables was one which had been manipulated in the major experiments of the project having to do with processes in concept attainment. For example, in experiment 16, three levels of concept complexity combined with three levels of incentives were administered to seventh and eighth grade subjects of high and low socioeconomic status. Thus the interactions of complexity with motivational status and subject characteristics was determined. In experiment 17 in which second grade children served as subjects, presentation method (simultaneous or successive) was factorially combined with four ratios of positive and negative instances. On the other hand, experiments 18 and 19 using college-aged subjects were mainly concerned with contrasting verbal and figural materials, a variable not explored in previous studies contained in this report.

[1]The following reports are based on data collected for three M.S. theses and a Ph.D. dissertation all under the direction of Herbert J. Klausmeier. Experiment 16 was conducted by Marcus C. S. Fang during the first semester of 1965-66. Experiment 17 was conducted by Nancy S. Smuckler during the second semester of 1965-66. James G. Ramsay conducted experiments 18 and 19, the former during the second semester of 1965, the latter, a PhD dissertation, during the second semester of 1967. The four reports were written by Elizabeth Schwenn and Herbert J. Klausmeier.

Experiment 16: Concept Complexity, Incentive, Social Class, and Concept Identification

Abstract

180 junior high school students from two SES levels (high vs. low) solved concept identification problems at three levels of complexity (1, 2, or 3 bits of relevant information) under three incentive conditions (monetary incentive, symbolic incentive, and no-incentive control). The subjects were shown the minimum number of stimulus slides which uniquely defined the concept and were asked to categorize the test slides which followed as either belonging or not belonging to the concept. Correct responses on the categorization task constituted the dependent variable. Subjects also responded to a posttest questionnaire designed to evaluate the success of the incentive manipulation as well as to assess the attitudes of subjects toward working for a reward versus working for the fun of it. Significant results indicated that the performance of the high socioeconomic subjects was better than that of the low socioeconomic subjects. As task complexity increased from 1 to 2 bits of relevant information, performance decreased. No further decrease was observed, however, when complexity was increased from 2 to 3 bits of relevant information. There was no difference in the number of correct responses made by subjects in the three incentive groups. The expected incentive x SES interaction also failed to materialize.

Purpose

The purpose of this experiment was to determine the effects of incentives and task complexity on the performance of students from two socioeconomic status levels on a concept identification task. A review of the literature reveals that the results of research on these variables have not been entirely consistent.

Studies which treat incentive as an independent variable essentially have dealt with four types of conditions: material incentives, symbolic incentives, feedback (or knowledge of results), and a no-incentive condition. Comparisons are usually made between the no-incentive condition and one or more of the others. The results of these studies have been equivocal--some indicating one type of incentive to be superior to another or to the no-incentive condition while others showed no difference among the incentive conditions. The present study in seeking to clarify the effects of incentive on concept identification utilized both monetary and symbolic incentive conditions.

One learner characteristic which has received much attention is the socioeconomic status (SES) of the subject. Estes (1956) and Amster and Marascuilo (1965) found subjects' performance not to be affected by their SES. However, Siller (1957) and Findlay and McGuire (1957) showed that children from high social-class backgrounds performed better than children from lower-class backgrounds. A number of studies (e.g.,

Terrell, Durkin, and Wiesley, 1959) have demonstrated that lower-class children learned more efficiently when given a material incentive than when given a symbolic incentive, while the opposite was true of middle-class children. The implication for efficient learning is far-reaching if the relationship holds for classroom situations; hence the present experiment is designed to provide a further test of the Terrell *et al.* findings.

Finally, research in the effects of task complexity has generally shown performance to deteriorate as complexity increases (e.g., Archer, 1954; Bourne, 1963). There is, however, no study, which has investigated the effect of incentives on performance when complexity is varied. It is conceivable that task complexity interacts with incentives such that the effect of incentives increases as complexity increases.

Subjects

A questionnaire following the procedures outlined in Hollingshead's (1957) *Two Factor Index of Social Position* was administered to 395 students which comprised the entire seventh and eighth grades at Monroe Junior High School, Monroe, Wisconsin. Ninety students with scores ranging from 11 to 34 (high SES) and 90 students with scores ranging from 51 to 73 (low SES) were selected as subjects.

Experimental Material

The stimulus materials were colored slides which contained geometric figures varying on three, four, or five bi-valued dimensions. The dimensions and their corresponding values were: number (*one* or *two*), color (*red* or *green*), texture (*plain* or *spotted*), shape (*circular* or *square*), size (*large* or *small*). Three conjunctive concepts at the same level of complexity (defined in terms of the number of bits of relevant information contained in the problem) were prepared for each group of subjects. Each concept was defined by a minimum number of slides (four slides in the 1-bit, five slides in the 2-bit, and six slides in the 3-bit relevant problems). The instances which defined the concept were arranged so that the first slide in each series was always a positive instance of the concept to be identified and each of the following slides varied only one dimension from the first slide or the preceding slide. Positive instances of the concept were labeled YES and negative instances were labeled NO. Following each defining set of instances eight test slides which were not labeled were presented to the subjects. The subject's task consisted of classifying the eight test slides as positive or negative instances of the concept just defined.

Experimental Procedure

The subjects were tested in groups of 20, with ten subjects from each SES level. All subjects were fully instructed as to the nature of the concept and the task requirements. Incentive subjects were told that those who responded correctly two-thirds of the time would receive $1.00 (monetary incentive) or a certificate of merit (symbolic incentive). At the conclusion of the experiment, the subjects filled out a posttest

questionnaire which was designed to evaluate the success of the incentive manipulation as well as to assess the attitudes of the subjects towards working for the sake of reward versus working for the fun of it.

Experimental Design

Subjects were randomly assigned to one of the 18 treatment groups generated by a 2 x 3 x 3 factorial design, with two levels of SES (high versus low), three types of incentive conditions (monetary, symbolic, and no-incentive control), and three levels of task complexity (1 bit, 2 bits, or 3 bits of relevant information). In additon, there were three problem types which differed only in terms of the particular dimensions relevant to problem solution. Thus each subject solved three problems at the same level of complexity.

Results

Performance was evaluated on the basis of the number of correct responses on the eight test instances. The mean number of correct responses for the treatment groups are contained in Table 16.1.

Table 16.1

Mean Number of Correct Responses for all Treatment Groups

Incentives	SES	Complexity 1	Complexity 2	Complexity 3	Incentive Means
Monetary	High	7.73	5.87	7.10	
	Low	6.77	6.03	5.59	6.46
Symbolic	High	6.77	6.03	6.47	
	Low	6.47	6.30	5.87	6.32
No-incentive control	High	7.17	6.90	6.90	
	Low	6.07	6.30	6.57	6.65
Complexity Means		6.78	6.24	6.41	

Statistically significant main effects were obtained for SES ($F = 11.59$; $df = 1/162$; $p < .01$), complexity ($F = 4.26$; $df = 2/162$; $p < .05$), and problem type ($F = 9.45$; $df = 2/324$; $p < .01$). Also, two interactions involving problem type were significant: complexity by problem type ($F = 5.21$; $df = 4/324$; $p < .01$), and incentive by complexity by problem type ($F = 2.50$; $df = 8/324$; $p < .01$). Neither the main effect of incentive nor any of the first-order interactions involving this variable were significant.

The mean number of correct responses for the high and low SES subjects was 6.73 and 6.21, respectively. Thus, the high SES subjects were found to be superior in performance to the low SES subjects. It was suspected that the difference between the SES groups was due, in part, to a difference in intellectual ability. A t test performed on the IQ scores of the two SES groups revealed that the mean IQ score (115.1) of the high SES group was significantly higher than the mean IQ score (106.8) of the low SES group ($t = 4.83$; $df = 178$; $p < .01$). This finding suggested that the superior performance of the high SES group was due to their higher intelligence and had little to do with their class membership. However, an analysis of covariance of the present data, using IQ score as the covariate, revealed a significant main effect of SES ($F = 9.37$; $df = 1/161$; $p < .01$) indicating that SES was a significant factor independent of intelligence.

As shown in Table 16.1, as complexity increases there is a general tendency for performance to deteriorate. When differences between the complexity treatment means were evaluated by the Newman-Keuls procedure, the only significant comparisons showed the 1-bit problem to be significantly easier than either the 2- or 3-bit problems.

Discussion

The failure to detect any significant effect due to incentive was not totally unexpected since Pavlik (1957), and Crawford and Sidowski (1964) have reported similar findings. One possible explanation for the lack of positive effects in the present study is that the motivation level of subjects participating in the experiment was uniformly high, thus offering an incentive had little influence upon their performance. Responses on the posttest questionnaire which indicated that subjects were highly motivated provide some evidence for this conclusion.

The present experiment failed to replicate the Terrell et al. (1959) finding that lower SES subjects perform better under a material incentive while higher SES subjects perform better under a symbolic incentive. Characteristics of the subjects might account for the difference in findings between the two experiments. It could be that children (in the Terrell et al. study) and adolescents (in the present study) do not place the same value on incentives. For instance, the middle-class child in the Terrell (1958) study had indicated that he "would rather do something for the fun of it" while the lower-class child had indicated that he "would rather do something if I am promised something for it." The same set of alternatives, when put to the adolescents in this study, did not elicit similar responses. Results showed that the high and low SES subjects did not differ in their responses, with 90 per cent of all subjects indicating that they would rather do something for the fun of it.

Differences in the nature of the experimental task might be another variable which could account for the discrepancy in results. In the Terrell et al. study subjects performed a simple discrimination task in which a button was matched with a correct stimulus. Perhaps this discrimination task becomes dull after a prolonged period whereas the

novelty of the concept identification task used in the present experiment holds the subjects' attention.

Another important variable might be the way the incentives are dispensed. If one examines the Terrell et al. methodology, one finds that the incentive more closely approximates a "reinforcer." That is, subject received a reinforcer (candy) after each correct response. Such immediate reinforcement has the dual function of strengthening the response as well as providing positive and immediate feedback. In the present study, however, subjects received neither reinforcement nor feedback throughout the experiment.

It seems reasonable that procedural differences may account for the failure to replicate Terrell's findings. Therefore, the failure to replicate the Terrell et al. results does not necessarily mean that the relationship between social class and the type of incentive does not exist. It does suggest, however, that such a relationship, if it exists, is not independent of such variables as age, nature of the experimental tasks, and the procedures for dispensing incentives.

The finding that high-SES subjects performed better than low-SES subjects is in agreement with the results of Siller (1957), and Findlay and McGuire (1957). This agreement is impressive in view of the fact that all of the experiments utilized widely different tasks. Moreover, the finding that SES exerts an influence which is independent of intelligence, confirms the importance of considering SES when the conceptual ability of subjects is a factor.

As mentioned previously, several studies (Archer, 1954; Bourne, 1963) have found that as the amount of relevant information increases performance decreases. The present study also found that performance deteriorated as the amount of relevant information increased from 1 to 2 bits. The present results, however, did not fully conform to the earlier findings since no further decrease in performance occurred when the amount of relevant information increased from 2 to 3 bits.

Finally, the significant effects of problem type merely indicates that there was a difference in difficulty depending upon the particular dimensions relevant to problem solution. It is difficult to account for significant problem effects in any systematic fashion. The first-order interaction of complexity by problem type and the second-order interaction of incentive by complexity by problem type are equally difficult to account for. Until a great deal more is known about such variables as salience and dominance of attributes, any attempt to interpret the effects due to problem type will more likely confuse the issue than clarify it.

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Experiment 17: Method of Presentation, Ratio of Positive to Negative Instances, and Concept Identification

Abstract

This experiment investigated the effect of two methods of presentation (simultaneous and successive) and four ratios of positive to negative instances (100, 75, 50, and 25 per cent positive instances) upon concept acquisition, transfer, and retention.

80 second grade subjects were randomly assigned to eight treatment groups and shown slides containing 40 geometric figures. Trapezoids (labeled Trapezoid) were designated as positive instances: all other figures (labeled No) were negative instances. Tests for acquisition were given at 8-figure intervals. To test for retention and transfer, subjects were required to identify trapezoids in a booklet containing 30 novel instances. The dependent variable was number of correct identifications of positive test instances. A control group of 10 subjects were administered the tests.

Method of presentation was statistically significant ($p < .05$) only in the acquisition phase and this was in favor of the successive presentation. Ratio of positive to negative instances affected both acquisition and transfer. In acquisition the 100, 75, and 50 per cent groups performed significantly better than the group receiving only 25 per cent positive instances. The latter group performed consistently below the chance level. In transfer the only significant difference favored the 100 per cent group over the other three conditions. This same trend was present in retention but was not significant.

Purpose

An important distinction which can be made in the area of conceptual learning is that between concept formation and concept identification. In concept formation the subject acquires a novel response which was not previously in his behavioral repertoire. In concept identification, however, the subject already has the necessary responses within his behavioral repertoire and he is simply asked to classify a laboratory environment in some predetermined way. Thus concept identification assumes prior existence of a concept, and requires identification of the predetermined classification scheme. It would appear that the majority of a child's learning activities would be appropriately characterized as concept formation.

In a survey of studies dealing with concept learning, (Klausmeier, Davis, Ramsay, Fredrick and Davies, 1965) many studies were found which investigated the variables and conditions associated with concept identification. For example, a number of investigators (Huttenlocher, 1964; Yudin and Kates, 1963; Olson, 1963) have employed school-age subjects in concept identification tasks in an attempt to delineate those conditions which result in optimal learning. Although the principles derived from concept identification experiments have frequently been extended to the classroom, failure to differentiate between concept identification and concept formation may lead to inappropriate applications of research findings.

The purpose of the present study was to investigate the effects of two variables in the concept formation of children. These variables, method of instance presentation and ratio of positive to negative instances, have been investigated extensively with college subjects using a concept identifcation task. For the most part, the evidence concerning method of presentation in concept identification is clear-cut; simultaneous presentation of instances results in superior performance when compared to successive presentation (Bourne, 1963; Cahill and Hovland, 1960; Hovland and Weiss, 1953). However, further research is necessary to determine the presentation method which will facilitate concept formation in children.

Research dealing with the ratio of positive to negative instances has resulted in widely divergent findings. Smoke (1933) using college students as subjects on a concept identification task involving geometric forms found performance for a group receiving all positive instances not to differ from the performance of a group receiving an equal number of positive and negative instances. Hovland and Weiss (1953), again using college students, found concept identification to be superior when all positive instances defined the concept. They also found that a 50 per cent ratio of positive to negative instances resulted in better performance than all negative instances. Finally, Huttenlocher, (1962) reported concept identification performance of seventh-grade subjects to be superior when mixed instances were employed. Clearly, further research is needed to determine the ratio condition which results in the most effective learning for concepts of varying types and subjects of varying characteristics.

In addition to concept acquisition, retention and transfer were also considered in the present study since little is known of the effects of method of presentation and ratio of positive to negative instances upon these two processes.

Subjects

The subjects were 90 second-grade pupils with a mean age of 8.2 years. In general they were from middle-class families, had limited experience with geometry, and had no formal experience with the concept trapezoid. The subjects were randomly assigned to one of eight treatment groups or a control group. Thus there were 10 subjects per group.

Experimental Material

In the acquisition task 40 labeled geometric figures were used as stimuli. Each positive instance, or trapezoid, was labeled "Trapezoid." Negative instances, figures not possessing one pair of parallel sides, were labeled "No." Positive instances varied across three dimensions: length of lines, degrees of angles, and orientation. Combinations of the first two dimensions were made so as to create 10 visibly distinct trapezoids. The 10 trapezoids were oriented in six different directions to produce a total of 60 trapezoids. Of the 60 instances formed by the various combinations of the three dimensions, 20 remained to be used as test instances. These positive instances were unlabeled. Of the 30 negative instances employed, 25 were quadrilaterals and 23 of these had two pair of parallel sides. The five remaining figures consisted of three triangles, an oval, and a circle. Negative instances also varied across the three dimensions of length of lines, degree of angles and orientation.

For the transfer and retention tests each subject received a three-page booklet containing instructions and 30 figures, 10 to each page. Half of the figures were positive instances while the remainder were negative instances. All figures used in the transfer and retention task were novel instances in that they had not been presented during acquisition.

Experimental Procedure

In acquisition, all subjects were presented, by means of a slide projector, eight training instances (labeled figures) followed by four test instances (unlabled figures). During the presentation of test instances, the subjects were asked to indicate whether the figure was, or was not, an example of the concept trapezoid by circling "Yes" or "No" on the appropriate line of an answer sheet. The control group was presented with the test instances and instructed to guess if they did not know what a trapezoid was. This procedure was followed until a total of 40 training and 20 test instances had been presented. In the successive treatment condition (Su) the training instances were presented serially. In the simultaneous treatment condition (Si) the eight training instances in each block of trials were presented

simultaneously. The test instances, however, were presented serially to all groups.

Instances were presented in the same order for both the Si and Su conditions. In the Su condition each of the eight training instances was exposed for 9.5 seconds. Total time taken to present all eight instances was 80 seconds. In the Si condition one slide containing eight training instances was exposed for 70 seconds. The reduction in total time was necessary in order to adjust for the slide changes in the Su condition. The test instances were each presented for 12 seconds.

The following four ratios of positive to negative instances were employed: for the 100 per cent condition eight positive instances were presented in each block; six positive and two negative instances were employed in the 75 per cent condition; four positive and four negative instances were presented in the 50 per cent condition; and two positive and six negative instances were employed in the 25 per cent condition.

For the transfer task, each subject received a test booklet containing 30 new geometric figures, half of which were trapezoids. The task consisted of having the subjects circle all figures thought to be trapezoids. The same test booklet was administered 48 hours later to measure retention.

Experimental Design

The experimental design for the acquisition task consisted of a 2 x 4 x 5 factorial design with two methods of stimulus presentation (simultaneous and successive), four ratios of positive to negative instances (100, 75, 50, and 25 per cent positive instances) and five blocks of four trials on which repeated measures were obtained. A total of eight cells were formed with ten subjects in each cell. Subjects participated in groups of ten, with a control group being considered separately. For transfer and retention the experimental design consisted of a 2 x 4 factorial design with two methods of presentation and four ratios of positive to negative instances.

Results

The total number of correct responses for each block of four test trials was the dependent variable used to assess performance on the acquisition task. The dependent variable used to assess performance on the transfer and retention tasks consisted of the total number of correct responses. Analysis of variance was employed to analyze each of the three tasks.

Acquisition. In Table 17.1 are found the mean number of correct responses for each ratio by method group listed across blocks. The four ratio means derived by summing across method and blocks are also presented. Method means are reported for each block under

which can be found the block means. The method means were 12.50 and 10.55 for Su and Si conditions respectively.

Table 17.1

Mean Number of Correct Responses Per Block of Four Trials

Ratio	Blocks 1		2		3		4		5		Ratio Mean-Total
	Si	Su	Si	Su	Si	Su	Si	Su	Si	Su	
P100	2.70	2.90	2.10	2.60	2.50	3.00	2.80	2.90	3.10	2.40	2.70
P75	2.00	3.00	1.90	2.50	2.60	3.00	2.20	2.80	2.50	2.90	2.54
P50	2.40	2.70	1.90	2.40	2.30	2.70	2.50	2.80	2.30	2.80	2.48
P25	1.60	2.10	1.20	1.50	1.10	1.30	1.30	1.50	1.20	1.20	1.40
Mean Method Totals	2.17	2.67	1.77	2.25	2.12	2.50	2.20	2.50	2.27	2.32	
Block Mean Totals	2.42		2.01		2.31		2.35		2.29		

The mean number of correct responses for subjects in the Su group differed significantly from the mean of the Si group (*F* = 5.98, *df* = 1/72, *p* <.05). Subjects under the Su conditions displayed superior performance to subjects under the Si conditions. As shown in Table 17.1, the superiority of the Su group was relatively consistent across blocks with the exception of the fifth blocks where the difference between the two treatments decreased.

Chance level of performance was determined to be 50 per cent. Figure 17.1 shows the per cent correct responses over blocks of four trials as a function of method of presentation. The Si group's performance was slightly above chance on Block 1. In the second block, performance declined to below chance level. The Si group's performance rose above chance level in the third block of trials and continued to rise in the remaining two blocks.

A significant main effect of ratio was found (*F* = 18.27, *df* = 3/72, *p* < .01). The Newman-Keuls procedure (Winer, 1962) for probing the nature of the differences among means was employed. Results of this analysis shows that the P100, P75, and P50 groups performed significantly better than the P25 group. From Figure 17.2 which shows per cent correct responses over blocks as a function of ratio condition it can be seen that the P50, P75 and P100 groups were consistently above chance level of performance. The P25 group's performance was invariably below this chance level.

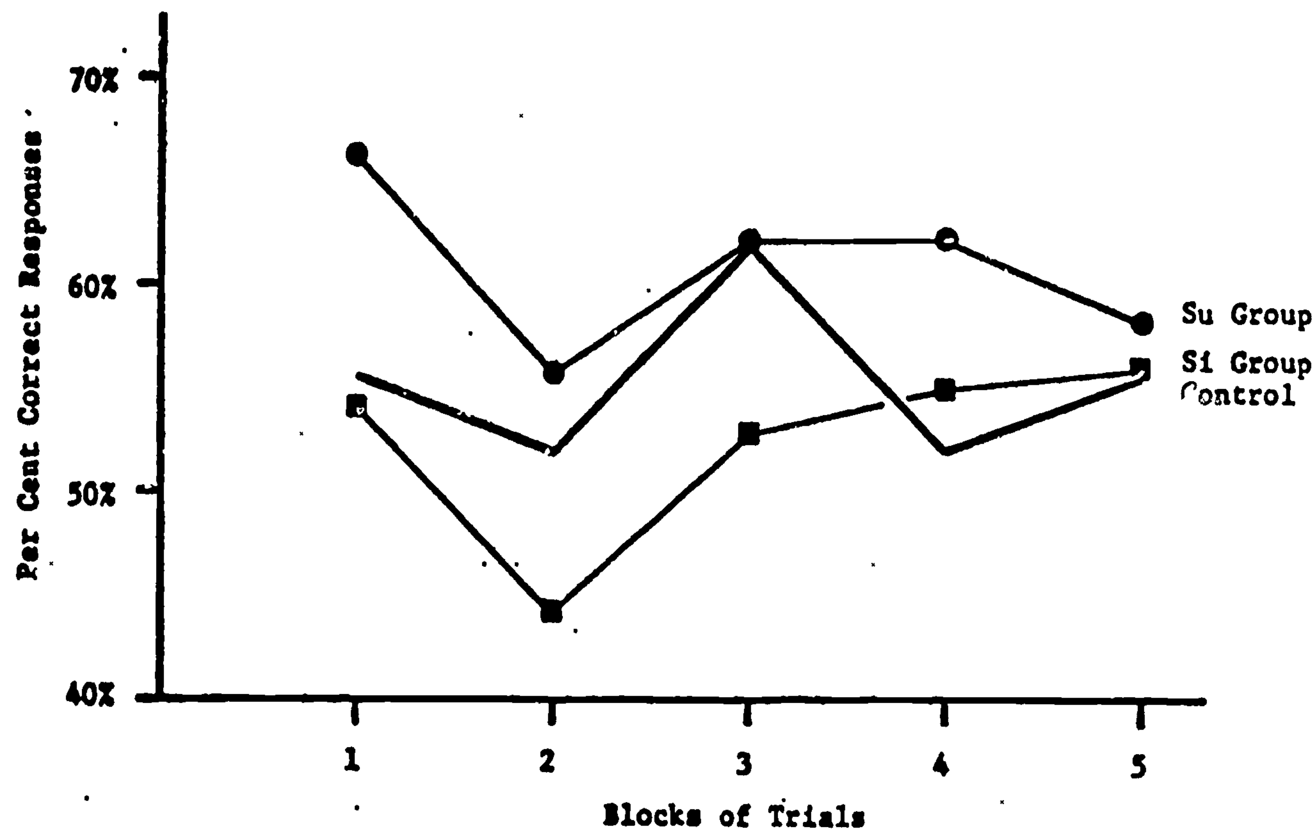

Figure 17.1 Per cent Correct Responses over Blocks of Four Trials as a Function of Method of Presentation.

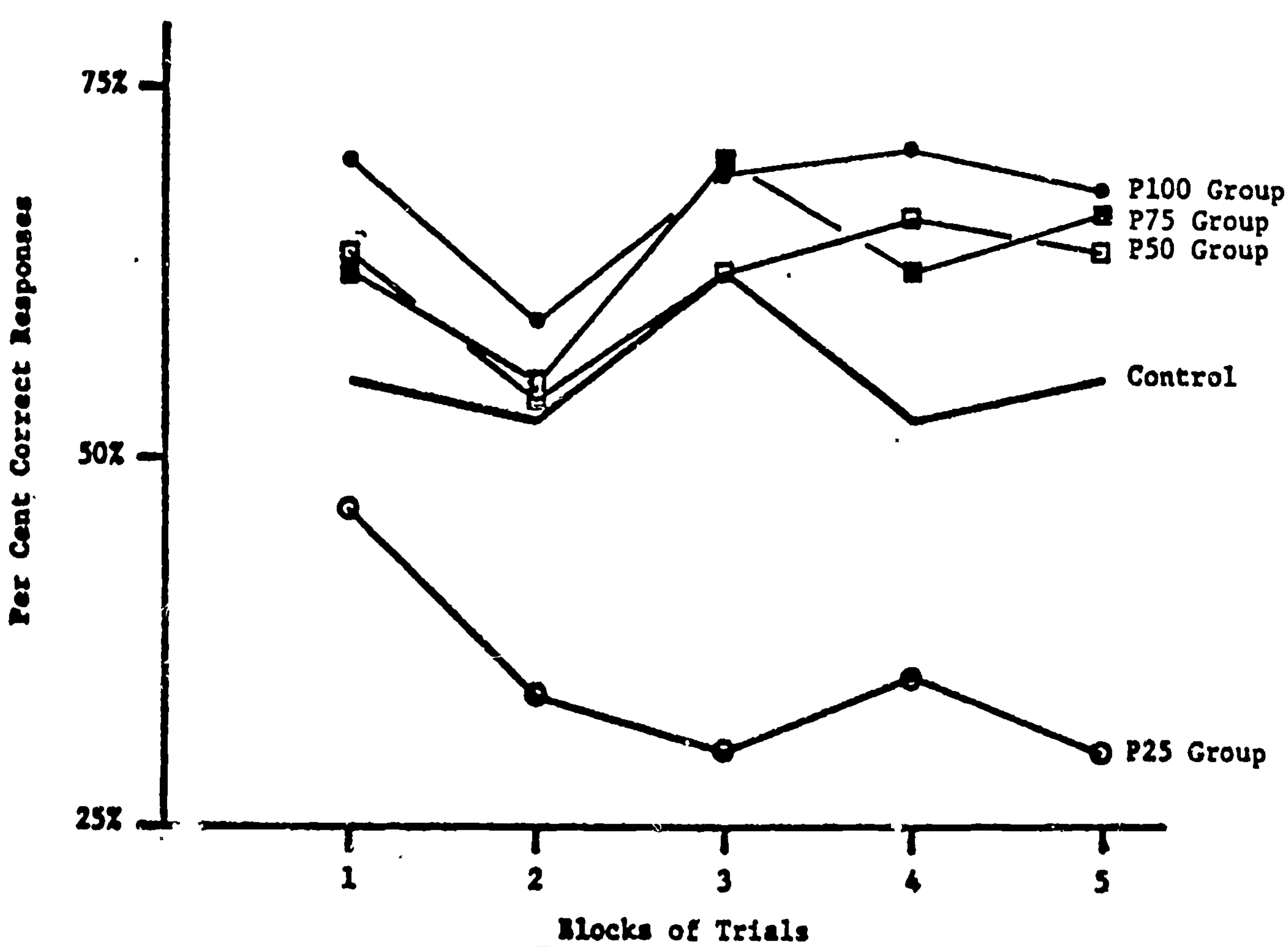

Figure 17.2 Per cent Correct Responses over Blocks of Four Trials as a Function of Ratio of Positive to Negative Instances.

A significant main effect of blocks was found ($F = 3.91$, $df = 4/288$, $p < .05$). When this effect was evaluated by means of the Newman-Keuls procedure a significant difference ($p < .05$) was found between blocks 1 and 2, reflecting a drop in performance from the first to the second block.

Transfer. Performance on the transfer task was evaluated on the basis of the number of correct responses. Table 17.2 contains the mean number of correct responses on the transfer task as a function of method of presentation and ratio of positive to negative instances during the acquisition stage. A two-way analysis of

Table 17.2

Mean Number of Correct Responses Transfer

Ratio	Method		Mean Ratio Total
	Si	Su	
P100	19.5	19.0	19.25
P75	17.6	16.6	16.8
P50	18.6	18.4	18.5
P25	16.5	17.8	17.1
Mean Method Total	18.05	17.75	

variance was employed to analyze the scores obtained from the 10 subjects in each of the eight treatment groups. The main effect of ratio of positive to negative instances was found to be significant ($F = 3.82$, $df = 3/72$, $p < .05$). The main effect of method did not yield a significant F ratio, nor did the first order interaction.

Subsequent analysis of the significant main effect of ratio of positive instances by the Newman-Keuls procedure revealed that the P100 group performed significantly better than the P25 and P75 groups. Although the P50 group did not significantly differ from the P25 and P75 groups, the mean number of correct responses made by the P50 group was higher than these other two ratio conditions.

Retention. Table 17.3 presents the mean number of correct responses for each ratio by method combination and an overall mean for each level of the main effects of method and ratio. An analysis of variance indicated that neither of the main effects nor their interaction was significant. Although differences between means were not significant, as they were in the analysis of the transfer data, a similar trend was indicated. That is, subjects in the P100 group made more correct

Table 17.3

Correct Responses Retention

Ratio	Method		Mean Ratio Total
	Si	Su	
P100	20.3	19.1	19.7
P75	16.8	18.1	17.4
P50	17.1	19.5	18.3
P25	17.3	18.2	17.7
Mean Method Total	17.8	18.6	

responses than subjects receiving the three lower ratios of positive instances. A slight superiority of the P50 group over the P75 and P25 groups is also indicated as was the case on the transfer task.

Discussion

In examining the effects of method of stimulus presentation upon concept acquisition, the present study found the successive presentation method to result in a significantly (.05) greater number of correct responses. The method factor was not found to be significant in either the transfer or retention phases. While method of presentation influenced concept acquisition, the method factor was not critical in the transfer or retention of the concept.

The ratio factor was found to be a more powerful variable. Ratio of positive to negative instances was disclosed as significant in both the acquisition and transfer tasks, .01 and .05, respectively. In considering concept acquisition it appears that the ratio variable was directly related to the percentage of correct responses. As the ratio of positive instances increased the percentage of correct responses increased. The P25 group made a significantly lower percentage of correct responses than the three higher ratio groups. The group receiving only positive instances gave a consistently higher percentage of correct responses across the five blocks of trials. Results illustrate the utility of employing a ratio of 50 per cent or more positive instances for effective concept formation.

Transfer to a 50 per cent ratio of positive to negative instances was most facilitated by the use of only positive instances during acquisition. The P100 group was significantly (.05) superior to the P75 and P25 groups. Subjects receiving a 50 per cent ratio did not differ significantly from the three other treatment groups. In contrast to the acquisition phase the P50 group made a higher percentage of correct responses on the transfer task than the P75 group. A marked

improvement was noted for the P25 group; the percentage of correct responses on the transfer task was almost double the percentage made in acquisition.

The ratio factor was not found to be significant in the retention phase, but the relative ranking of the four treatment groups on the dependent variable was similar to the ranking in the transfer phase. The P100 condition resulted in the highest percentage of correct responses, followed by the P50 condition; the P25 group made more correct responses than the P75 group. Retention appeared to be maximal with a 100 per cent positive ratio.

Method of presentation did not interact with ratio of positive to negative instances in any of the three tasks. The influence of the method and ratio factors appears to be differential under the three tasks.

The finding that the successive method of presentation resulted in a significantly (.05) greater number of correct responses during acquisition is inconsistent with the general trend of findings of concept identification studies. Most studies (Bourne, 1963; Cahill and Hovland, 1960; Hovland and Weiss, 1953) have reported the superiority of the simultaneous method. Inconsistent findings could be attributed to fundamental task differences, the age disparity of the subject population sampled, the influence of extraneous factors such as stimulus presentation interval, or the stimulus media employed.

Crouse and Duncan (1963) and Bourne, Goldstein and Link (1964) reported time to be a factor when considering method of presentation. For the simultaneous method to be superior to the successive, a longer presentation interval was necessary. In the present study presentation time was equated. Nadelman (1957) found that the efficiency of attaining concepts with the use of simultaneous and successive presentation was influenced by the stimulus media used. Drawings required fewer prompts per concept when presented successively as opposed to simultaneously. With models the simultaneous method resulted in superior performance. In the present study stimuli were presented by means of slides which resembled drawings more closely than three-dimensional models.

Several other considerations become apparent in examining the method results. The subjects were required to form a relatively small number of concepts. However, their task was a difficult one due to the utilization of a large proportion of four-sided figures as negative instances. Gagné (1965) distinguishes eight types of learning, each beginning with a different state of the organism and ending with a different capability for performance. In order for concept learning to occur a subject must be able to make multiple discriminations. The superiority of the successive presentation method might be attributed to the difficulty experienced by young subjects in discriminating the difference between trapezoids and four-sided negative instances in the simultaneous condition. The retarded discrimination would, in turn, hinder the development of concept learning.

The paucity of experiments concerned with the influence of the method of presentation employed during acquisition upon the transfer of a concept inhibits the drawing of generalizations. In the present study the method of stimulus presentation, although significant in acquisition, had no appreciable effect on the transfer task. The lack of a significant finding suggests that the method of presentation employed during acquisition will have little influence on a subsequent transfer task. As far as retention is concerned, the state of knowledge with regard to the variable of method of presentation is similar to the findings presented in the transfer literature. Little evidence is given as to which method of presentation will maximize the retention of a concept. The findings of the present study indicate that the method of presentation employed during concept acquisition will not influence concept retention.

In discussing acquisition, the present experimental finding that ratios of 100, 75, and 50 per cent positive instances were significantly (.01) superior to a ratio of 25 per cent positive instances is consistent with the results reported by a number of experimenters. Whitman and Garner (1963), Dominowski (1965), and Kurtz and Hovland (1956) reported the use of 100 per cent positive instances to be most advantageous in facilitating performance. Related to the experimental trend disclosing the superiority of 100 per cent positive instances are the results presented by Mayzner (1962) and Freibergs and Tulving (1961). Learning was facilitated when the number of positive instances was increased and the number of negative instances was decreased.

The results of the present study are in agreement with these experimental trends. The P25 group's performance was significantly (.01) inferior to the three higher positive ratio groups. Although no significant differences were found between the P50, P75, and P100 groups, graphic representation of acquisition curves revealed that the P100 group was consistently superior to the P50 and P75 groups; the P75 group made a higher percentage of correct responses than the P50 group. Thus, the findings of the present concept formation study are in accordance with the results of many concept identification experiments. The use of all positive instances leads to the most efficient concept formation.

The P25 group performed less well than the control group and was below the chance level of responding. Several factors, either singularly or in combination, could account for the significantly inferior performance of the P25 group. The ratio employed may have retarded discrimination due to the high preponderance of negative instances and the low frequency of trapezoids. Difficulties in discrimination may have occurred. Subjects had to differentiate between four-sided figures with one pair of parallel sides and four-sided figures with two pair of parallel sides. The subjects set to respond may have been involved. Since a large proportion of the labeled instances were negative the subjects might have expected a large proportion of the unlabeled instances to be negative. An unlabeled test instance could also have been considered negative due to previous experience

with a large variety of negative instances. In other words, unfamiliar test instances were subsumed within the class of negative instances due to the perceived broadness of the class.

In interpreting the results of the present study concerning the effect of ratio on transfer one should look closely at the type of transfer task employed. In contrast to the Fryatt and Tulving (1963) study in which interproblem transfer was observed, the present study employed intraproblem transfer. In the interproblem situation, the subjects are given a series of different concept identification problems and within this series the problems consist of all positive, negative or mixed instances. Thus what is presumed to develop and transfer from problem to problem is the subject's ability to utilize information presented in these various forms to solve distinct problems. In the intraproblem transfer situation, the subject is presented with novel instances which, however, represent the same concept. One would expect the degree of learning in the acquisition stage to heavily influence the amount of transfer in this latter situation. This, of course, is what was found in the present study. The P100 group which was superior during acquisition maintained this superiority in transfer. The argument that degree of learning was the primary factor affecting transfer is strengthened when one considers method of presentation. That is, the fact that the Si and Su groups had reached about the same level of learning at the end of acquisition would account for the lack of difference between these conditions in transfer.

The marked improvement of the P25 group on the transfer task is of interest. On block five of the acquisition task 30.0 per cent of the responses of this group were correct as compared to 57.2 per cent on the transfer task. On the test trials the P25 subjects performed consistently below change level while on the transfer task their performance was slightly above chance. If one considers the nature of the test trials and the transfer task an explanation for this shift in performance becomes apparent. On the test trials all instances were positive. Assuming that subjects receiving only 25 per cent positive instances during training trials had formed a set to expect a large proportion of negative instances they would be led by such a set to label test instances as negative thereby obtaining a low score. The same set operating on the transfer task where half of the instances were in fact negative would result in a score close to the chance level of 50 per cent which indeed was found for this group.

Lack of experimental evidence prevents the drawing of conclusions as to which ratio of positive to negative instances employed during acquisition will maximize retention. In the present study the main effect of ratio was not significant on the retention test.

Unlike the Hovland and Weiss (1953) study the present experiment did not find an interaction between method of presentation and ratio of positive to negative instances. However, Hovland and Weiss examined concept identification, sampled a different subject population, and made statistical comparisons across three experiments.

The repeated measure of blocks of trials was utilized in the acquisition phase so that measures of performance could be taken at intervals throughout acquisition. Although the blocks effect was not one of the variables under investigation, this main effect merits attention due to the significance (.05) disclosed and the failure of all treatment groups to conform to the usual acquisition curve. Subsequent analysis of the block effect by means of the Newman-Keuls procedure disclosed a significant difference between the first and second block of trials. All eight treatment groups gave a lower percentage of correct responses in the second block. Since the four ratio groups were presented with different proportions of positive instances, only two instances, both positive, were common to all treatment groups. The possibility exists that these common positive instances were difficult for the subjects to discriminate as trapezoids due to their angles, lengths of lines, and orientation. More likely, the decline in performance was related to two of the test instances which the subjects had difficulty in differentiating as trapezoids, apparently due to the length of lines and orientation of these test figures.

The present study examined the stimulus variables of the method of presentation and the ratio of positive to negative instances under three tasks in order to gain further information toward the goal of promoting efficient concept learning. Unlike previous experiments manipulating the two stimulus variables, a concept formation task, rather than a concept identification task, was employed. It could be argued that the task was not concept formation, that the subjects were merely required to make a perceptual discrimination. Since all test instances were positive the subjects were credited with a correct answer if they circled Yes on their sheets. However, all training instances were labeled figures. The label was also associated with the correct response by means of instructions. Subjects were requested to circle Yes if the figure was a trapezoid. The subjects' task in the present study falls under the conditions which Gagné (1965) delineates as necessary for concept learning. Gagné explains that the prerequisite of multiple discrimination learning must be achieved by the subject in order that concept learning may occur.

Situational conditions must include specific stimulus objects that have a common characteristic. In the present study all subjects received a minimum of 25 per cent positive instances. All positive instances were quadrilaterals possessing one pair of parallel sides.

Gagné also reports that the subjec must be able to identify additional instances of the class using new stimuli. In the present study test instances varied from training instances across the three dimensions of length of lines, degree of angles, and orientation. All instances employed in the transfer task were novel. Gagné feels that to test for the presence of concepts it is necessary to demonstrate that generalization may occur, generalization to a variety of specific instances of the class that have not been used in learning.

In considering the task conditions employed in the present study, it becomes apparent that a direct comparison to concept identification literature was necessitated because of the paucity of concept formation experiments manipulating the independent variables of method and ratio. The present study was limited in that the goal was to determine the effects of the independent variables of method of presentation and ratio of positive to negative instances upon the acquisition, transfer, and retention of the geometric concept trapezoid.

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Experiment 18: Type of Material, Group Size and Concept Learning

Abstract

Concept attainment of pairs and individuals was studied using two stimulus array boards containing identical material, one verbal and one figural. Four different sequences of four concepts were presented to 96 university students. Performance was assessed with two dependent variables: time-to-criterion, and total number of card choices. It was found that pairs were in general equal or superior to individuals in concepts. Concepts embedded in figural material were easier to attain than concepts embedded in verbal material. When ordinal position of the concept in the sequence was plotted against three dependent variables, it was found that performance was poorest on the first concept, that it improved markedly on the second concept, and that improvement continued for the third and fourth concepts. The four different sequences in which the problems were presented led to statistically significant differences in performance as measured by time-to-criterion Several alternative explanations were suggested to account for these results.

Purpose

The present experiment was undertaken to clarify the effects of type of material and group size on concept learning since contradictory findings have been reported for both of these variables.

In one study where the effect of type of material on concept attainment was tested, it was found that concepts were more easily attained when pictures of objects were employed than when the written names of the objects were used (Davidon, 1952). However, Runquist and Hutt (1961) found the opposite to be true.

Where performance of groups on problem solving tasks is compared with that of individuals, findings are again ambiguous. Duncan (1959), in a comprehensive review of the literature, concluded that individuals were superior to groups. Several studies (e.g., Tuckman and Lorge, 1962; Restle and Davis, 1962) however, have found groups to be superior to individuals.

In view of the conflicting evidence concerning the above variables, the present experiment was designed to: (1) compare the performance of pairs and individuals on a concept attainment task; and (2) determine the effects of two types of material, figural and verbal, on concept attainment behavior.

Subjects

The subjects were 96 students, 64 females and 32 males with a mean age of 21.6 years, who participated in the experiment as a requirement for an introductory course in educational psychology at the University of Wisconsin.

Experimental Materials

Two types of material, figural and verbal, were used. The figural stimuli were 64 instances generated from the 2^6 combinations of values of

the following dimensions; color of figure (red or green), shape of figure (circle or ellipse), size of figure (large or small), number of figures (one or two), number of borders (one or two) and continuity of borders (broken or solid). The figural instances were printed on 3 x 3 inch cards and randomly arranged into an eight row by eight column array. A similar verbal array was constructed. Where a figural instance directly displayed one large red circular figure with two broken borders, the corresponding verbal instance gave the same information in words.

Four concepts were randomly selected, each with two relevant dimensions, with a given concept partitioning the array into 16 positive and 48 negative instances. The concepts were (a) two borders, green figures, (b) broken borders, elliptical figures, (c) two, circular figures, and (d) small, red figures.

Experimental Procedure

The subjects participated in the experiment individually or in pairs. They were scheduled at their convenience and upon reporting to the laboratory were seated in front of a stimulus array which was laid flat on a table. The experimenter described the array in terms of its dimensions and values, and defined the term "concept" in relation to the array. Examples were given until the subject or pair could describe instances and concepts used to classify instances as positive or negative. The experimenter then described the task as a game in which he had a concept in mind and the individual or pair had to identify the concept. The rules of the game were as follows: (1) Experimenter would point to one positive instance of the concept he had in mind. (2) The subject or pair would select other instances and experimenter would say "yes" if a card selected was a positive instance, "no" if it was a negative instance. (3) When the subject or pair wanted to try to guess the concept, the values which defined the concept being considered were checked with a pencil on a slip listing all the dimensions and values and the slip was passed to the experimenter. (4) If the hypothesis was correct the game ended and a new one began; if incorrect, the experimenter would say "incorrect" and the subjects would continue choosing cards and offering hypotheses until they identified the concept. Pairs were instructed to work as a team.

If the subject or pair was unable to identify the first concept in 20 minutes or the second concept in 15 minutes, a replacement was run. Five individuals and four pairs were replaced. The experimenter recorded card choices and time taken to identify the concept.

Experimental Design

The experiment was a 2 x 2 x 4 factorial design with two types of material (figural or verbal), two numbers of subjects (individuals or pairs) and four sequences of the four concepts. The four sequences were arranged in a Latin square. Individuals and pairs were randomly assigned to treatment groups with the restriction that there were three female pairs or individuals and one male pair or individual in each of the 16 treatment groups.

Results

Two dependent measures were used to assess performance: time-to-criterion and total number of card choices. A three-way analysis of variance (ANOVA) with the assumption of fixed effects was applied to each dependent measure.

The ANOVA on time-to-criterion revealed that type of material was a significant effect ($\underline{F}$ = 16.02, $\underline{df}$ = 1/48, $\underline{p}$ < .01) as was sequence of concepts ($\underline{F}$ = 4.10, $\underline{df}$ = 3/48, $\underline{p}$ < .05). Neither the main effect of size of group nor any of the interactions was a significant source of variation. The means of groups for which significant $\underline{F}$ - ratios were obtained are presented in Table 18.1. As can be observed from this table, subjects working with verbal materials took, on the average, 8.55 minutes longer to attain the concepts than did subjects working with figural materials.

Table 18.1

Mean Time-to-Criterion for Groups Producing Significant $\underline{F}$ - ratios

Significant Effect	Group	Mean (in Minutes)
Type of Material	Figural	16.15
	Verbal	24.70
Sequence	b-c-d-a	16.81
	c-b-a-d	17.24
	d-a-b-c	21.62
	a-d-c-b	26.04

It can also be noted from Table 18.1 that sequences containing concepts (a) and (d) in the first position produced longer times-to-criterion than sequences in which these concepts appeared in the final position.

For the ANOVA on total number of card choices, number of subjects was the only significant source of variation ($\underline{F}$ = 8.43, $\underline{df}$ = 1/48, $\underline{p}$ < .01). Pairs averaged 50.94 card choices; individuals, 71.44 card choices.

Discussion

For the comparison of the figural and verbal materials, the results suggest that information was more readily available from the figural instances. It was found that subjects attaining concepts with verbal material took a longer time-to-criterion than subjects working with figural material, however, the total number of card choices in reaching the criterion did not differ for the two materials. From this it can be concluded that less time was spent per card choice in the figural than in the verbal condition. This supports the notion that a subject in the figural condition needed only a brief glance at an instance to determine the presence of any particular value of a dimension. The verbal instances

appear to have been less discriminable from each other. The ease of discrimination of values is of primary importance when strategies for obtaining information are considered. Such strategies have been described by Bruner, Goodnow, and Austin (1956) and by Klausmeier, Harris, and Wiersma (1963). In each case, the gathering of information proceeded with the discrimination of values on instances and the noting of changes in values from instance to instance.

The results of the present study also suggest that pairs working as a team were more efficient in gathering information when compared to individuals. The subjects working alone took as long as the pairs to reach criterion, but made significantly more card choices. From this result it can be inferred that individuals obtained less information from each instance. Another possible interpretation is that the members of a typical pair had, between them, a superior memory capacity when compared with the typical individual. The information on a previously selected instance would thus have a better chance of being recalled by one or the other of the members of a pair than by the individual working alone. Thus the pairs would need fewer card choices in order to regather forgotten information.

In another study (Klausmeier, Wiersma, and Harris, 1963) with a task identical to the one used in the present study, larger groups of subjects learned initial concepts more efficiently, but were less efficient when identifying concepts as individual subjects in a transfer task. The present study supports the findings of Klausmeier _et al_. for the initial task.

The significant effect of sequence of concepts in the analysis of time-to-criterion suggests that transfer may occur with particular sequences of concepts. The two easiest sequences had concepts (a) and (d) last while the two most difficult sequences had concepts (a) and (d) first. Concepts (a) and (d) both had color as a relevant dimension. It may have been that subjects in the difficult sequences came to regard color as relevant in every problem and had to break this set in order to achieve success on the last two problems.

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Experiment 19: Type of Material, Type of Classification and Concept Learning

Abstract

36 college subjects categorized stimulus cards into four categories. Two kinds of instances were employed, figural and verbal. The figural instances were 16 H-patterns derived from the 2^4 combinations of the following four binary dimensions: size (large or small), color (red or green), number (one or two) and orientation (upright or tilted). The verbal materials were 16 nouns which could be divided into groups of four on the basis of associations with four categories. The categories which were conjunctive combinations of values of two binary dimensions were: hard-white (e.g., bone), soft-white (e.g., rabbit), hard-brown (e.g., chestnut), and soft-brown (e.g., cork). The figural and verbal instances were classified according to zero (R-0), one (R-1), or two (R-2) relevant dimensions. In the R-2 figural condition, the four categories were: large-green patterns, large-red, small-green, and small-red. The four verbal categories were white-hard, white-soft, brown-hard, and brown-soft. In the R-1 condition the categories for figural instances were; green, red, large and small. For the verbal instances the categories were white, brown, soft and hard. In the R-0 condition no value of any dimension was consistantly paired with a particular category. A subject served in only one of the six conditions resulting from the 2 x 3 combination of type of material and type of classification rule. The task was self-paced and the subject indicated his response to each instance by pressing one of four buttons corresponding to the four categories. Immediate feedback with correction was given. The dependent variables were time-to-criterion, the criterion being 16 correct responses in a block of 16 instances and number of correct responses.

The results in terms of number of correct responses indicated that for both types of material increasing the number of relevant dimensions defining the categories led to a decrease in difficulty of categorization. For the R-0 and R-1 conditions verbal materials were clearly superior to figural materials. However, at R-2 the figural materials were slightly easier. The mean time spent viewing each figural instance was 9.4 seconds; the corresponding time for verbal instances was 6.6 seconds. Type of classification rule had no effect on viewing time. An explanation of the differences between figural and verbal materials in terms of differential amounts of interference was suggested.

Purpose

Experimenters interested in describing concept learning in a quantitative fashion and in manipulating the amount of information transmitted by various instances tend to use figural stimuli generated by combinations of values of binary dimensions (e.g., Bulgarella and Archer, 1962; and Bruner, Goodnow and Austin, 1956). Underwood and Richardson (1956), on the other hand, developed a set of verbal materials to study concept learning as a form of verbal learning. It is to a comparison of dimensionalized figural material and the verbal materials

generated by Underwood and Richardson that the present study was addressed. In addition, with these two types of material, the effect of three types of classification was explored.

Subjects

The subjects were 36 volunteers, all males, residing in the Regent Apartments of the University of Wisconsin. The mean age of the subjects was 19.4 years. One subject failed to understand the instructions and was replaced.

Experimental Materials

The set of figural instances used for the present study was 16 H-patterns, the 2^4 combinations of the values of the following four binary dimensions: size (large or small), color (red or green), number (one or two), and orientation (upright or tilted). A description of the set of figural materials employed in this experiment is presented in Table 19.1. The values of dimensions have been coded in the following manner: one = 1, two = 2, large = L, small = s, red = r, green = g, upright = u, tilted = t.

Table 19.1

The 16 Figural Instances in Three Types of Classifications

Type of Classification	Category 1	Category 2	Category 3	Category 4
	(large-green)	(large-red)	(small-green)	(small-red)
	1-L-g-u	1-L-r-u	1-s-g-u	1-s-r-u
R-2	2-L-g-t	2-L-r-t	2-s-g-t	2-s-r-t
	2-L-g-u	2-L-r-u	2-s-g-u	2-s-r-u
	1-L-g-t	1-L-r-t	1-s-g-t	1-s-r-t
	(green)	(red)	(large)	(small)
	1-L-g-u	1-L-r-u	1-L-g-t	1-s-g-u
R-1	2-L-g-t	2-L-r-t	2-L-g-u	2-s-g-t
	2-s-g-u	2-s-r-u	2-L-r-u	1-s-r-u
	1-s-g-t	1-s-r-t	1-L-r-t	2-s-r-t
	(-----)	(-----)	(-----)	(-----)
	1-L-g-u	1-L-g-t	2-L-g-u	2-L-g-t
R-0	1-s-g-t	2-s-g-t	1-s-g-u	1-s-g-u
	2-L-r-u	1-L-r-u	2-L-r-t	1-L-r-t
	2-s-r-t	2-s-r-u	1-s-r-t	1-s-r-u

Underwood and Richardson (1956) published a set of verbal materials to be used in the study of concept learning. These materials were a list of 213 nouns, subsets of which were associated with 40 descriptive adjectives. An adjective (e.g., soft) was considered to be a concept, and nouns associated with the adjective (e.g., rabbit, cork, bread) to be instances of the concept. Many of the adjectives were values on dimensions. Some of the dimensions and values were hardness (hard, soft), color (red, brown, white, green), size (big, small) and texture (rough, smooth, fuzzy).

Because of the kinds of classifications of instances which were to be used in the study, it was decided to identify 16 nouns which could be divided into groups of four on the basis of associations with four categories. These categories would be the conjunctive combinations of values of two binary dimensions. The dimensions of hardness (hard or soft) and color (white or brown) were selected and instances were identified from the Underwood and Richardson list which had associations with hard-white, soft-white, hard-brown, and soft-brown. Four instances were found for each of the first two categories, but one was lacking for the category hard-brown and three for the category soft-brown. There were likely instances for these categories (e.g., acorn, mink) which did not appear on the Underwood and Richardson list.

A list of likely instances was presented to 20 subjects, volunteers from the staff of the Wisconsin Research and Development Center for Cognitive Learning. The task was to identify those nouns which could be described as hard, soft, big, small, white, or brown. The procedure of Mayzner and Tresselt (1961) was used. From these data, the instances chestnut, gavel, and bronze were selected for the category hard-brown, and mink was selected as an instance of the category soft-brown. The complete set of verbal instances, and the three types of classifications of these instances are presented in Table 19.2.

The figural and verbal instances were classified according to zero (R-0), one (R-1) or two (R-2) relevant dimensions. In the R-2 figural condition, category 1 represented large-green patterns, category 2 large-red, category 3 small-green, and category 4 small-red. In the corresponding verbal condition, category 1 represented nouns associated with white-hard, category 2 white-soft, category 3 brown-hard, and category 4 brown-soft. In the R-1 condition, one dimension was relevant to each category. For the figural instances the categories were: 1-green, 2-red, 3-large, and 4-small; for the verbal instances the categories were: 1-white, 2-brown, 3-hard and 4-soft. In the R-0 condition, no value of any dimension was consistently paired with a particular category.

The figural instances were photographed in color and mounted in slide frames. The verbal instances were typed on mimeograph stencils, cut out and mounted in slide frames.

Table 19.2

The 16 Verbal Instances in Three Types of Classifications

Type of Classi-fication	Category 1	2	3	4
	(white-hard)	(white-soft)	(brown-hard)	(brown-soft)
	bone	rabbit	gavel	cork
R-2	salt	linen	chestnut	mink
	enamel	bread	acorn	chamois
	skull	sheep	bronze	moccasin
	(white)	(brown)	(hard)	(soft)
R-1	bone	gavel	salt	cork
	skull	bronze	enamel	rabbit
	linen	mink	chestnut	sheep
	bread	chamois	acorn	moccasin
	(-----)	(-----)	(-----)	(-----)
	bone	skull	salt	enamel
R-0	bread	sheep	linen	rabbit
	bronze	acorn	gavel	chestnut
	chamois	moccasin	mink	cork

Experimental Procedure

The presentation of instances and feedback information was fully automated. The apparatus consisted of three units: a four channel response unit, a tape reader, and a Kodak Carousel slide projector. The response unit housed four response buttons, eight feedback lights (a red and a green light over each button) and a projection screen. A continuous loop of tape was punched with correct responses and fed through the tape reader. This unit, in conjunction with the response unit controlled the feedback lights, while the response unit controlled the slide advance.

The subjects participated individually. They received instructions as to the classification they would learn and the operation of the apparatus.

The function of the apparatus can be clarified by the following sequence of events. (1) An instance was presented. (2) The subject, who was self-paced, pushed the response button corresponding to his choice of a category. (3) The instance was removed and if the subject had correctly categorized the instance the green feedback light over the button he pushed came on; if he was incorrect, the red feedback light came on over the button he pushed and the green feedback light came on over the correct button. The light(s) remained on for four seconds. (4) The next instance appeared. The experimenter recorded total time-to-criterion from a stopwatch.

Experimental Design

The two independent variables were type of classification (2, 1, or 0 relevant dimensions) and type of material (figural or verbal instances). A 2 x 3 factorial design was used with six replications in each of the six treatment groups. A two-way fixed effects analysis of variance model was assumed.

Results

Criterion performance on the task was 16 correct responses in a block of 16 instances. The task was terminated if the subject did not reach this criterion in 240 trials. A score of total number of correct responses was given to each subject. For those subjects who reached criterion before 240 trials were completed, a number of correct responses was added to their score such that this number plus the total number of the responses they had made to criterion summed to 240 trials.

The analysis of variance showed the main effects of Material ($\underline{F}$ = 153.75, $\underline{df}$ = 1/30, $\underline{p}$ < .001), Classification ($\underline{F}$ = 119.06, $\underline{df}$ = 2/30, $\underline{p}$ < .001) and their interaction ($\underline{F}$ = 46.58, $\underline{df}$ = 2/30, $\underline{p}$ < .001) to be significant. The means for the treatment groups are contained in Table 19.3.

Table 19.3

Mean Number Correct for Treatment Groups

Type of Classification	Type of Material: Figural	Verbal
R-0	M = 80.67	M = 176.50
R-1	M = 99.17	M = 205.00
R-2	M = 227.00	M = 220.67

From Table 19.3 it is apparent that, in general, verbal materials led to less difficulty in correct categorization of instances than did figural materials. The mean number of correct responses for figural materials was 135.61; that for the verbal materials was 200.72. The superiority of the verbal materials over the figural materials held when there were zero and one relevant dimensions for categorization. However, with two relevant dimensions the verbal material was slightly more difficult than the figural material. In general, increasing the number of relevant dimensions defining the categories led to a decrease in difficulty of categorization. The mean numbers correct were 128.59, 152.09, and 223.84 for R-0, R-1, and R-2 respectively.

Subsequent one-way analyses of variance for the figural and verbal conditions showed type of classification to be a significant effect for both the figural condition ($\underline{F}$ = 153.51, $\underline{df}$ = 2/30, $\underline{p}$ < .001) and the

verbal condition ($F = 12.12$, $df = 2/30$, $p < .001$). Six t tests (all with $df = 30$) revealed significant differences between R-1 and R-2, and between R-0 and R-2 for the firgural material and between R-0, and R-1, and between R-0 and R-2 for the verbal material. In each one-way
and between R-0 and R-2 for the verbal material. In each one-way
analysis, the mean square error from the initial two-way analysis was retained for the denominator of the F ratio. This error term was also used as the estimate of error variance in the t tests.

The total time-to-criterion in seconds for each subject was divided by the total number of responses made to criterion. The resulting number indicated the mean time the subject had spent on each instance. From a two-way analysis of variance on these scores it was determined that subjects who had observed the figural instances took a significantly longer mean time per instance than subjects who had observed the verbal instances ($F = 11.22$, $df = 1/30$, $p < .01$). Neither Type of Classification nor the interaction of Type of Material and Type of Classification were significant effects. The mean time per instance for subjects in the figural condition was 9.43 seconds; for subjects in the verbal condition, 6.57 seconds.

Discussion

The results of the present experiment support the conclusion that the difficulty in learning to classify instances is an inverse function of the number of relevant dimensions determining the classification, where the number of relevant dimensions was zero, one or two. The conclusion regarding type of material is somewhat more complex. Verbal instances were clearly easier to categorize in the R-0 and R-1 conditions; in the R-2 condition performance was nearly the same for both types of instances.

From the reports of labeling (collected from each subject at the end of the experiment), one possible interpretation of the results can be presented. All of the subjects in the R-2 figural group and four out of the six in the R-2 verbal group gave the experimenter-defined labels, the values of the two relevant dimensions, when asked to label the response buttons. In the R-1 situation, however, only one subject in the figural group was able to give the experimenter-defined labels while all subjects in the verbal group gave one or more of the experimenter-defined labels, although no subject in this group completely replicated the experimenter-defined categories. It was evident that subjects in the verbal R-1 condition had less difficulty in labeling the buttons than did subjects in the R-1 figural condition. The use of verbal labels as mediators may have facilitated performance. By this same reasoning one would expect better performance with figural materials in the R-2 condition since the labels were more readily available to the subjects. This, as mentioned above, was the case.

Another interpretation of the results rests on the assumption of interference occurring as a joint function of type of classification and type of material. According to this interpretation, in the R-0 condition there was interference occurring with both types of material but to a greater degree for the figural material. This interference was minimized in the R-1 verbal group. At R-2, interference was minimized

in the figural group. For this interpretation to be tenable, however, the source of the interference must be specified.

Consider first the R-0 condition. In this condition, figural instances were more difficult to categorize correctly than verbal instances. Interference may have been reduced in the latter condition if the subjects responded to each instance as a whole rather than as a complex of values on dimensions. In contrast to this, the figural instances may have been remembered on the basis of their entire set of figural values so that a subject needed to remember that button 1, for example, was the correct response for <u>one</u> <u>large</u> <u>green</u> <u>upright</u> pattern. The finding that longer time per instance was spent on figural material than on verbal material could be attributed to this analytical vs. holistic perception of the two types of materials. If this difference in the perception of the two types of material occurred, then interference between figural instances could occur among any of the values making up the instances while interference between verbal instances could occur only on the basis of the unitary item which the verbal instance represented.

In the R-1 condition it could be postulated that the same kind of differential perception of the materials occurred resulting in continued interference for the figural group. Assuming that the verbal instances were responded to as single items, the presence of one consistent associative value (label) for each response button would contribute to the similarity of the set of four items associated with each button thus decreasing interference.

In the R-2 condition, the attention given to the specific values of the figural instances could have been highly facilitative to performance since this would be a way to identify which values were relevant to a particular button and which were not. The perception of the verbal instances as single items in the R-2 condition may have prevented the identification of relevant dimensions. It should be noted that this second interpretation based on interference is not independent of the first interpretation since labels are postulated as a means for reducing interference in the R-1 and R-2 conditions.

Obviously the interpretations offered are post hoc; the study was designed simply to determine the effects of the independent variables. Now that Type of Classification and Type of Material have been shown to be powerful variables, further experimentation can be designed to deal with the explanation of their effects.

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Strategies and Cognitive Processes in Concept Learning: Final Report

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RETRIEVAL TERMS

Ability

Cognitive Ability

Cognitive Processes

Concept Formation

Factor Analysis

Information Processing

Learning Processes

Retention

Thought Processes

IDENTIFIERS

ABSTRACT

The nature of a concept was explicated in terms of four characteristics: definability, structure, psychological meaningfulness and utility. A concept learning strategy was seen to be comprised of three sets of cognitive processes:- analyzing the situation, securing information, and processing information. A series of 19 controlled experiments and factor-analytic studies was carried out to clarify the nature of concept learning strategies and their component cognitive processes. A total of 2,062 elementary, high school, and university students served as subjects for the experiments. Instructions formulated to enable subjects to cognize the attributes of the concept population, to cognize the rule joining the attributes, and to draw correct inferences from positive and negative concept instances facilitated concept learning. Subjects offered hypotheses in a systematic predictable pattern which was related to the informative feedback which they had received on preceding problems. Successive presentation of concept instances, random order of instance recall, and shorter stimulus exposure time, (variables assumed to increase memory load), resulted in poorer retention scores. High-analytical subjects were superior to low-analytical subjects in ability to process information and attain concepts. Factor-analytic studies related an induction factor to concept-attainment tasks, and suggested that more complex concept learning tasks require higher-level abilities than simpler tasks.